Quasi-Experimental Evaluations of Pediatric Health Care: Clinical Practice Guidelines and Insurance Coverage

Quasi-Experimental Evaluations of Pediatric Health Care: Clinical Practice Guidelines and Insurance Coverage

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Abstract

The underlying theme of this dissertation is the effects of clinical and federal policy on health, utilization, and expenditures among children and young adults. In Chapter 1, I evaluate the clinical and economic benefits of clinical practice guidelines recommending universal cerebrospinal fluid testing in the emergency department for febrile infants aged 29-56 days. Using a difference-in-differences approach and administrative data from 31 U.S. children's hospitals, I find that these guidelines are not associated with better clinical outcomes or lower health care spending, suggesting that many families of older infants could be spared the stress associated with cerebrospinal fluid testing without harm. The optimal management of older febrile infants in the emergency department has been debated for decades, and results from this study have the potential to change clinical practice at the hospital level.

In Chapter 2, I assess the impact of the Affordable Care Act dependent coverage provision on health care utilization, health, and health care expenditures among young adults aged 19-25 years. Using a difference-in-differences analysis of nationally representative data, I find that implementation of the provision was associated with improved self-reported health and improved financial protection against the costs of health care among young adults. These findings highlight the importance of continued efforts to expand insurance coverage in this population.

In Chapter 3, I investigate whether insurance coverage loss drives differences in access and health care utilization between older adolescents and young adults with asthma. I find that young adults with asthma are less likely to have a usual source of

care, to use outpatient care, and to fill asthma medication prescriptions compared with older adolescents with asthma. Differences in insurance coverage account for large proportions of these differences. In a longitudinal analysis, I also find that older adolescents with asthma who lose insurance coverage as they transition to young adulthood are less likely to have a usual source of care. Taken as a whole, these results suggest that insurance coverage plays a crucial role in ensuring access to care and encouraging optimal health care utilization patterns for adolescents and young adults with asthma.

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Acknowledgements

This dissertation would not have been possible without the guidance of my Ph.D. committee (Kathy Swartz, Ben Sommers, and Michael McWilliams). I am deeply indebted to each of them for demonstrating exemplary mentorship and for supporting me both personally and professionally throughout my time at Harvard.

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Above all, I am grateful to my wife Sara for constantly reminding me that the true measure of a research career is real-world impact and for providing unwavering emotional support during the up and downs of graduate school. While obtaining a Ph.D. from Harvard is no small feat, there is no doubt that my most important accomplishments during the past four years are marrying her and having our absurdly cute daughter, Adelaide.

For my mom, Sara, and

super-baby Adelaide

Chapter 1: Association between Cerebrospinal Fluid Testing Guidelines and Clinical Outcomes among Febrile Infants Aged 29-56 Days

INTRODUCTION

According to national U.S. clinical practice guidelines (CPGs), infants aged 0-28 days who present to the emergency department (ED) for evaluation of fever should undergo urine, blood, and cerebrospinal fluid (CSF) testing to facilitate prompt diagnosis of urinary tract infections, bacteremia/sepsis, and meningitis.[1-3] However, the management of older febrile infants aged 29-56 days in the ED is controversial and has been debated in the literature for decades.[4-10] While there is general agreement that older febrile infants should undergo urine and blood testing, no such consensus exists for CSF testing.[1,2] Universal CSF testing for older febrile infants could prevent missed or delayed diagnoses of bacterial meningitis, leading to better clinical outcomes and lower health care spending. On the other hand, if providers can accurately identify which older febrile infants need CSF testing after considering clinical presentation and results from other laboratory testing, universal CSF testing could increase spending without improving clinical outcomes.

Based on well-known but differing criteria to identify febrile infants at low-risk for serious bacterial infections, some U.S. children's hospitals have adopted CPGs recommending universal CSF testing in the ED for older febrile infants, while others have adopted CPGs recommending selective CSF testing after considering other factors.[11] To date, no study has compared the clinical and economic benefits of these approaches. While randomization would be ideal for causal inference, such an approach would be infeasible due to the practical and ethical difficulties of enrolling sufficient

numbers of young infants to potentially undergo an invasive procedure like lumbar puncture.

The objective of this study was to evaluate the association between hospital CPGs recommending universal CSF testing in the ED for older febrile infants and clinical outcomes, as well as the association between these CPGs and health care spending. We used a quasi-experimental approach that exploited the variation in CSF testing recommendations among CPGs for older febrile infants at U.S. children's hospitals. Specifically, we examined hospitals with and without CPGs recommending universal CSF testing in the ED for older febrile infants and compared the differences in clinical outcomes and spending between these hospital groups among older febrile infants to the corresponding differences among younger febrile infants.

METHODS

Study design

We compared 7 hospitals with CPGs recommending universal CSF testing in the ED for older febrile infants aged 29-56 days (CPG group) with 24 hospitals without such CPGs (control group). In the control group, 8 hospitals had CPGs recommending selective CSF testing in the ED for older febrile infants meeting specific criteria, while 16 did not have CPGs guiding management of older febrile infants in the ED (de facto selective CSF testing).

We used a difference-in-differences analysis to estimate differences in clinical outcomes and spending between comparison groups among older febrile infants that were not predicted by the corresponding differences among younger febrile infants. An important advantage of this approach is that it adjusted for differences in patient

characteristics between the comparison groups that did not vary with age. For example, even if infants' severity of illness at presentation differed systematically between the CPG and control group, the effect of this confounder would be netted out by our comparisons of older versus younger infants, as long as the difference in illness severity was the same in both age groups.

Data source

Data for this study were obtained from the 2007-2013 Pediatric Health Information System (PHIS), an administrative database containing encounter-level information from 45 non-profit, tertiary U.S. children's hospitals affiliated with the Children's Hospital Association (Overland Park, Kansas, USA). Participating hospitals provide discharge data for inpatient, ED, and observation unit visits, including demographic information, International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes, ICD-9 procedure codes, and charges for clinical services.[12] Because the PHIS contains de-identified data, the Institutional Review Board of Boston Children's Hospital deemed this study exempt from review.

Study sample

We defined older febrile infants as ages 29-56 days and younger febrile infants as ages 7-28 days. We excluded infants ages 0-6 days because of the unique clinical circumstances during the immediate perinatal period.[5] Following other studies, we excluded eight of the 45 PHIS hospitals with previously described data quality problems or missing data for ED visits.[13] To assign the remaining hospitals to the CPG and control groups, we determined the presence, content, and implementation year of CPGs for older febrile infants based on a previously administered survey of ED medical directors at

PHIS hospitals.[11] Of the 37 hospitals in the survey, we excluded four due to non-response, one due to data quality issues with the spending variable, and one due to inaccurate discharge diagnosis information for ED visits, leaving 31 hospitals in the sample.

For each hospital in the sample, we excluded patient data from years before CPGs were implemented, if implemented during the study period. Following this exclusion, there were 423,948 discharge records for infants aged 7-56 days who presented to the ED of the 31 hospitals. We excluded 1,257 records with missing billing or discharge diagnosis data. We further excluded 24,136 records with discharge diagnosis codes indicating a complex chronic condition[14] (e.g., congenital heart disease) since febrile infants with these conditions often undergo non-standard evaluations in the ED,[13] yielding 398,555 potentially eligible records.

Following previous research on the management of febrile infants, we further restricted the sample to records with one of the following four fever-related codes in a discharge diagnosis or admission diagnosis field: 780.6 (Fever and other physiologic disturbances of temperature regulation), 780.60 (Fever, unspecified), 780.61 (Fever presenting with conditions classified elsewhere), and 778.4 (Other disturbances of temperature regulation of infant).[3,13] We also included records with an infection-related admission or discharge diagnosis code that predicted a complete sepsis evaluation (urine, blood, and CSF testing) for at least 50% of infants aged 7-28 days (see Appendix 1.1 and Appendix Table 1.1 for further details). Our strategy was based on the assumption that complete sepsis evaluations are good proxies for fevers among infants aged 7-28 days. In support of this assumption, previous research indicates that most febrile infants ≤ 28 days

old undergo these evaluations in PHIS hospital EDs.[3] Complete sepsis evaluations are less likely to predict fevers among febrile infants aged 29-56 days, who less frequently undergo these evaluations.[13] As such, we did not include these infants when screening diagnosis codes.

In a sensitivity analysis, we restricted the sample to records with one of the four fever-specific diagnosis codes in a discharge diagnosis or admission diagnosis field. In other sensitivity analyses, we constructed the sample using infection-related diagnosis codes that predicted complete sepsis evaluations for at least 25% or 75% of infants aged 7-28 days, instead of 50%.

Study variables

The clinical outcome was the occurrence of an adverse event, which we defined as any of the following during the initial episode of care or during any readmission within three days of discharge: in-hospital mortality (based on the PHIS disposition variable); central venous catheter placement (based on ICD-9 procedure codes); mechanical ventilation (based on charges or ICD-9 procedure codes); extracorporeal membrane oxygenation (based on charges or ICD-9 procedure codes); or a medical complication (based on ICD-9 discharge diagnosis codes indicating an infectious or vascular complication due to medical care, drug reaction, or blood transfusion reaction). We selected these events as potential indicators of complications from bacterial meningitis that would expectedly be more prevalent among patients with delayed or missed diagnoses of bacterial meningitis. Although these adverse events could result from many other conditions, we would not expect CSF testing to affect the diagnosis and treatment of other conditions. Therefore, our difference-in-difference estimates should reflect

effects of universal CSF testing on adverse events secondary to delayed or missed diagnoses of bacterial meningitis only.

We assessed spending associated with the initial episode of care and any readmissions beginning within three days of discharge from the initial episode of care. To ensure that differences in spending reflected differences in utilization and not prices, we analyzed a standardized spending measure that equaled the standardized unit price of a clinical service multiplied by the number of units billed, summed over all services. The standardized unit price for each service was based on the median of unit costs (based on charge-to-cost ratios) among PHIS hospitals.[15] We converted standardized spending to 2013 dollars using the general U.S. Consumer Price Index.[16]

Statistical analysis

We used logistic regression to model the occurrence of an adverse event as a function of age group (older versus younger febrile infant) and its interaction with CPG group status (CPG versus control). We included an indicator for each hospital (omitting a reference hospital) to control for hospital-specific factors common to younger and older febrile infants, such as geographic location and the case mix of infants served by the hospitals. Covariates were the patient's race/ethnicity, gender, primary insurance payer, median annual household income by zip code of residence, season of discharge, and discharge year. We used robust variance estimators to account for clustering at the hospital level.[17]

Using a generalized linear model with a log link, we similarly modeled standardized spending as a function of the same terms.[18] To improve interpretability, we

retransformed regression estimates to probabilities or dollars using simulation. Further details on the regression models and simulation procedure are available in Appendix 1.2.

The coefficient of the interaction between age group and CPG group is the difference-in-differences estimate, or the mean difference between the CPG and control groups among older febrile infants that was not predicted by the corresponding difference among younger febrile infants and not explained by any differences in covariates that changed with age group. A positive difference-in-differences estimate would suggest that CPGs recommending universal CSF testing for older febrile infants were associated with an increase in the outcome, whereas a negative difference-in-differences estimate would suggest these CPGs were associated with a decrease in the outcome.

Our difference-in-differences analysis relied on the assumption that differences in adverse events or standardized spending between the CPG and control groups would have been the same among older and younger febrile infants in the absence of differences in CSF testing recommendations for older febrile infants. We performed several tests of this assumption. First, we compared differences in observed patient characteristics between comparison groups among older febrile infants with the corresponding differences among younger febrile infants. The existence of differences that varied with age would suggest potential bias from differences in unobserved characteristics present in older febrile infants but not in younger febrile infants. Second, we assessed whether differences between the CPG and control group varied with age for management decisions other than CSF testing, including urine testing, blood testing, parenteral antibiotic use, and hospitalization. Additional analyses assessing the validity of the study's underlying assumption are described in Appendix 1.3.

Estimates could be biased if the probability of readmission to a non-PHIS hospital differed between comparison groups, since any clinical outcomes or spending associated with readmissions to a non-PHIS hospital would not be captured by our dataset. This potential bias would be more likely to exist if the practice of selective CSF testing in the control group led to fewer hospitalizations and therefore a higher chance of readmission, and if PHIS and non-PHIS hospitals frequently shared patients in the same market. To test for this bias, we compared the proportions of hospitalized older febrile infants between comparison groups and excluded 14 hospitals located in metropolitan statistical areas with at least one other general children's hospital in a sensitivity analysis.[19] The excluded hospitals had lower market share than hospitals without nearby competitors (Appendix 1.4). In additional sensitivity analyses, we excluded the 16 hospitals without CPGs for older febrile infants from the control group and excluded infants who did not undergo any testing during the initial episode of care, since these infants may not have been truly febrile.

We performed analyses using SAS 9.4, Stata 13.0, and R version 3.1.1. Two-sided p values < 0.05 were considered significant.

RESULTS

Of 82,047 records meeting sample inclusion criteria, we excluded 6.0% due to missing covariate data, leaving 77,076 records in the main sample. When we included records with missing covariate data but did not adjust for these covariates in regressions, results did not change substantially. For analyses of spending, we excluded an additional 3.9% of records due to missing or inaccurate spending data, leaving 74,207 records.

The CPG group included 17,949 records (6,747 from younger febrile infants and 11,202 from older febrile infants), while the control group included 59,127 records (22,868 from younger febrile infants and 36,259 from older febrile infants). Among younger febrile infants, CPG and control groups had similar proportions of females and infants of Asian or other race/ethnicity; different proportions of infants of Hispanic, black, and white race/ethnicity; and different proportions of infants in each category of annual median household income by zip code and primary insurance payer (Table 1.1). Differences between comparison groups were similar among older and younger febrile infants except in two categories of race/ethnicity (Hispanic and black) and primary insurance payer (public insurance and self-pay/other). Although statistically significant, the differences between age-related group differences for these characteristics were small (< 2.6 percentage points).

Febrile infant management profiles by age are displayed in Figure 1.1. The proportion of younger febrile infants undergoing CSF testing was higher ($p<0.001$) in the CPG group (68.0%) than in the control group (64.0%) (Table 1.2). The proportion of older febrile infants undergoing CSF testing was higher ($p<0.001$) in the CPG group (64.7%) than in the control group (46.9%), while the proportion of older febrile infants hospitalized following the initial ED visit was similar ($p=0.30$) between the CPG (52.4%) and control (51.9%) groups. For hospitalization, differences between comparison groups were similar among older and younger febrile infants. For urine testing, blood testing, and parenteral antibiotic use, the differences between age-related group differences were statistically significant but small (< 6.3 percentage points) compared to the corresponding difference for CSF testing (14.2 percentage points).

Age profiles in adverse events and standardized spending are displayed in Figure 1.2. CPGs recommending universal CSF testing in the ED for older febrile infants were not associated with significant differences in the probability of adverse events (difference-in-differences: +0.36 percentage points; 95% CI -0.14 to 0.88; p=0.18) or standardized spending (difference-in-differences: $195; 95% CI -$543 to $991; p=0.63) (Table 1.3). Results from sensitivity analyses did not substantively differ from our main analysis (Table 1.4).

Table 1.1. Age-related group differences in demographic characteristics

	Older febrile infants (n = 47,461)		Younger febrile infants (n = 29,615)		Age-related group differences		
Demographic characteristic (%)	**CPG group**	**Control group**	**CPG group**	**Control group**	**CPG - control: older febrile infants[a]**	**CPG - control: younger febrile infants[a]**	**Difference-in-differences[b]**
GENDER							
Female	44.6	44.4	44.4	44.2	0.2	0.2	0.0
RACE/ETHNICITY							
Hispanic	23.7	31.2	21.7	31.1	-7.5*	-9.4*	1.9*
Black (non-Hispanic or ethnicity unknown)	24.5	20.5	26.6	20.9	4.0*	5.7*	-1.7*
Asian (non-Hispanic or ethnicity unknown)	2.5	2.0	2.4	2.3	0.5*	0.1	0.4*
Other (non-Hispanic or ethnicity unknown)	6.9	7.0	7.4	7.0	-0.1	0.4	-0.5
White (non-Hispanic or ethnicity unknown)	42.4	39.4	42.0	38.8	3.0*	3.2*	-0.2
MEDIAN ANNUAL HOUSEHOLD INCOME BY ZIP CODE							
$0 to $30,000	26.5	19.9	25.7	19.6	6.6*	6.1*	0.5
$30,001 to $50,000	52.1	55.3	53.8	55.4	-3.2*	-1.6*	-1.6
$50,001 to $70,000	16.3	18.8	15.5	18.7	-2.5*	-3.2*	0.7
> $70,000	5.1	6.0	5.0	6.3	-0.9*	-1.3*	0.4
PRIMARY PAYER							
Private insurance	37.7	23.6	38.0	24.2	14.1*	13.8*	0.3
Public insurance	51.5	68.7	52.7	67.3	-17.2*	-14.6*	-2.6*
Self-pay or other	10.9	7.8	9.3	8.5	3.1*	0.8*	2.3*

Abbreviations: CPG, clinical practice guideline

*$p < 0.05$

[a]p value was derived from a chi squared test.

[b]This column refers to the difference between age-related group differences and equals (CPG - control among older febrile infants) - (CPG - control among younger febrile infants). We fitted logistic regression models modeling each characteristic as a function of the indicator of age group (older vs. younger febrile infant), the indicator for CPG group (CPG vs. control), and their interaction. The p value was derived from the hypothesis test that the coefficient of the interaction term equaled zero.

Table 1.2. Age-related group differences in management decisions

	Older febrile infants		Younger febrile infants		Age-related group differences		
Management decision (%)	**CPG group**	**Control group**	**CPG group**	**Control group**	**CPG - control: older febrile infants[a]**	**CPG - control: younger febrile infants[a]**	**Difference-in-differences[b]**
Urine testing[c]	75.9	72.0	71.0	69.9	+3.9*	+1.1	+2.8*
Blood testing	78.5	75.1	76.1	75.6	+3.4*	+0.5	+2.9*
CSF testing	64.7	46.9	68.0	64.4	+17.8*	+3.6*	+14.2*
Parenteral antibiotic	58.8	52.2	72.4	72.1	+6.6*	+0.3	+6.3*
Hospitalization	52.4	51.9	77.4	78.3	+0.5	-0.9	+1.4

Abbreviations: CPG, clinical practice guideline; CSF, cerebrospinal fluid

*$p < 0.05$

[a]p value was derived from a chi squared test.

[b]This column refers to the difference between age-related group differences and equals (CPG - control among older febrile infants) - (CPG - control among younger febrile infants). We fitted logistic regression models modeling each characteristic as a function of the indicator of age group (older vs. younger febrile infant), the indicator for CPG group (CPG vs. control), and their interaction. The p value was derived from the hypothesis test that the coefficient of the interaction term equaled zero.

[c]For definitions of management decisions, see Appendix 1.1.

Table 1.3. Unadjusted means of dependent variables and adjusted difference-in-differences estimates

	Unadjusted means				Adjusted difference-in-differences estimates		
	Older CPG	**Older control**	**Younger CPG**	**Younger control**	**Estimate[a]**	**95% CI[a]**	**P value**
Adverse events (%)	2.22	1.84	3.10	3.07	0.36	-0.14, 0.88	0.18
Standardized spending ($)	4,168	5,027	6,501	8,111	195	-543, 991	0.63

Abbreviations: CPG, clinical practice guideline; CI, confidence interval

[a]For adverse events, estimates and 95% confidence intervals were multiplied by 100 and represent absolute percentage point differences. For standardized spending, estimates and 95% confidence intervals represent absolute differences in dollars.

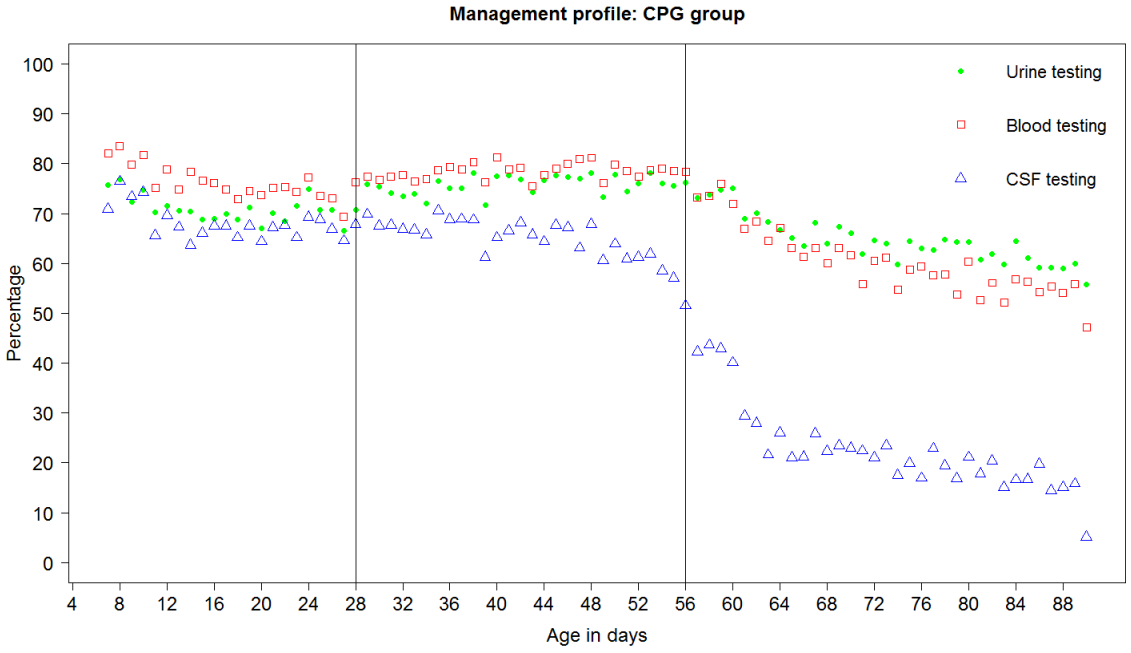
Table 1.4. Results from sensitivity analyses

	Adverse events			Standardized spending		
	Estimate[a]	95% CI[a]	P value	Estimate[a]	95% CI[a]	P value
Use fever-specific diagnosis codes to construct a more specific, less sensitive sample	0.19	-0.03, 0.45	0.12	14	-626, 662	0.97
Use diagnosis codes predicting a complete sepsis evaluation at least 25% of the time among infants aged 7-28 days to construct sample	0.24	-0.32, 0.88	0.43	259	-521, 1071	0.52
Use diagnosis codes predicting a complete sepsis evaluation at least 75% of the time among infants aged 7-28 days to construct sample	0.15	-0.24, 0.61	0.49	-121	-852, 578	0.74
Exclude 14 PHIS hospitals with other children's hospitals in the same metropolitan statistical area	0.40	-0.32, 1.11	0.28	216	-654, 1128	0.64
Exclude 16 hospitals without CPGs for older febrile infants from the control group	0.23	-0.46, 0.97	0.52	247	-510, 1061	0.53
Exclude two hospitals from the CPG group that demonstrated lower compliance with their CPGs	0.27	-0.22, 0.83	0.32	148	-692, 1058	0.74
Exclude infants who underwent no urine, blood, or CSF testing	0.34	-0.31, 1.07	0.30	-51	-893, 771	0.91

Abbreviations: CI, confidence interval; CPG, clinical practice guideline; CSF: cerebrospinal fluid

[a]For adverse events, estimates and 95% confidence intervals were multiplied by 100 and represent absolute percentage point differences. For standardized spending, estimates and 95% confidence intervals represent absolute differences in dollars.

A.



B.

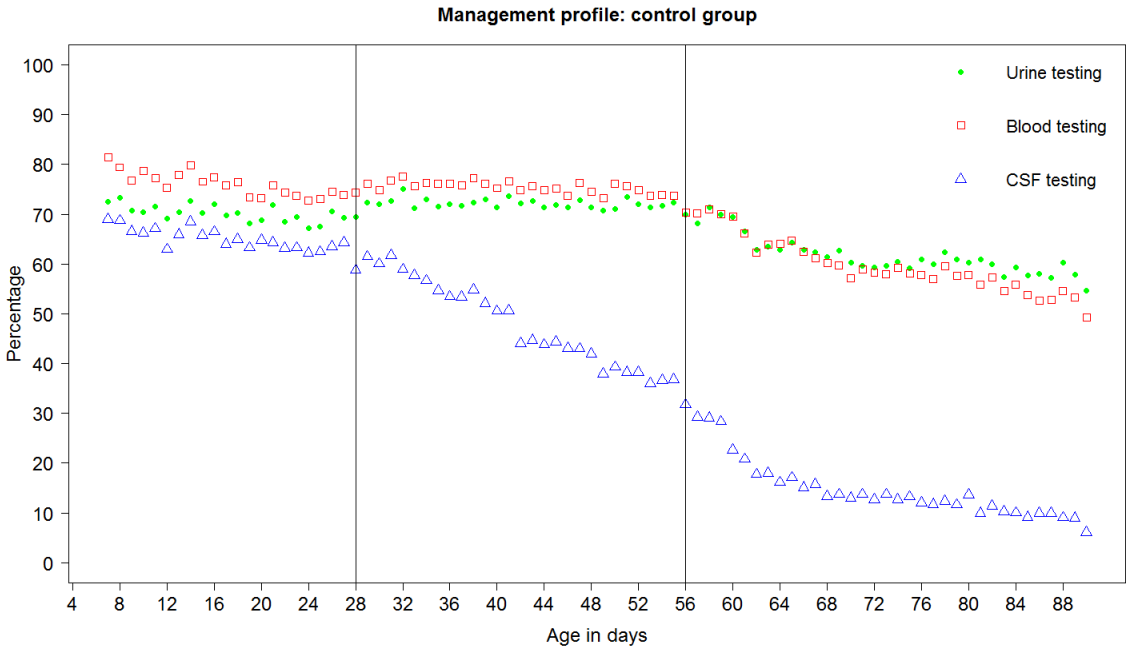
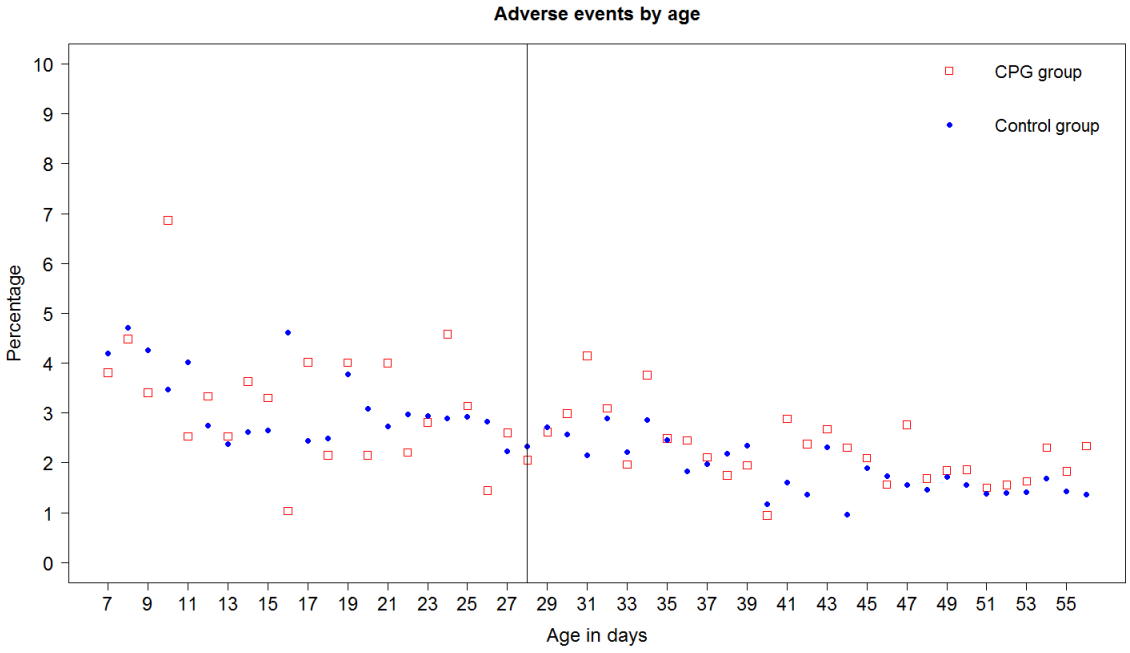


Figure 1.1. Hospital management profile by age. Circles represent urine testing, squares represent blood testing, and triangles represent cerebrospinal fluid testing. A) CPG group; B) Control group.

A.



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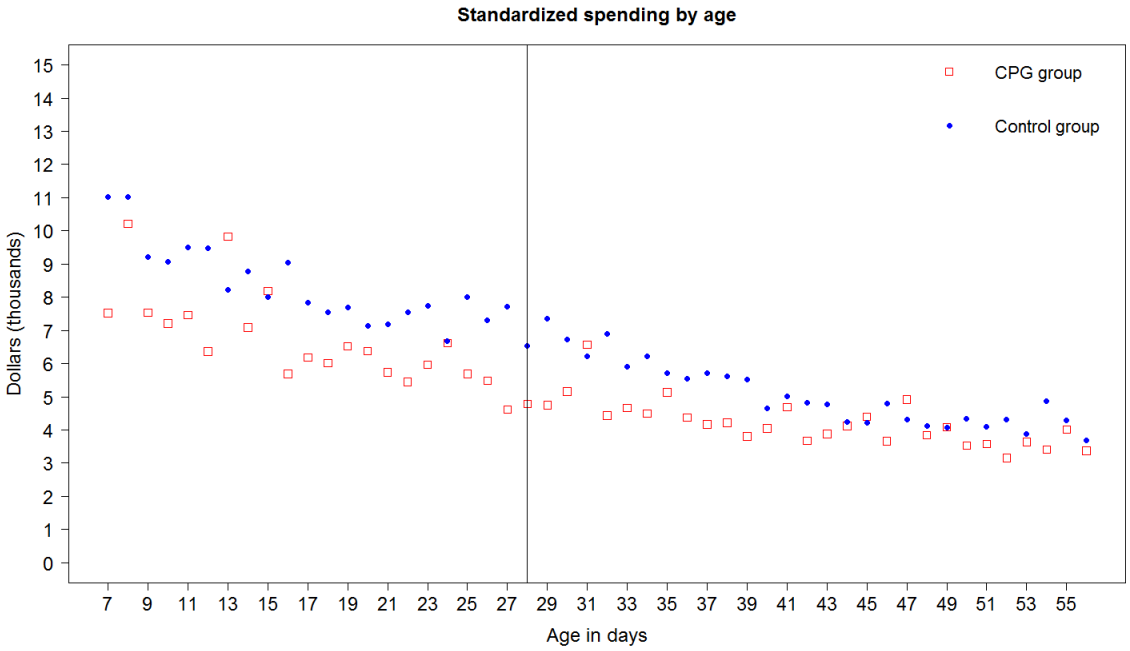

Figure 1.2. Adverse events and standardized spending by age in the CPG and control groups. Squares represent the CPG group, and circles represent the control group. A) Adverse events; B) Standardized spending.

DISCUSSION

In this study of 31 large U.S. children's hospitals, hospital CPGs recommending universal CSF testing for older febrile infants were not associated with better clinical outcomes or lower spending. Although CSF testing confers important clinical benefits for certain older febrile infants, our findings do not support a clear clinical or economic benefit of CPGs recommending CSF testing for all older febrile infants.

The lack of a significant association between these CPGs and adverse events in our study suggests that providers in the control group were able to accurately determine which older febrile infants were at high-risk for bacterial meningitis after considering clinical and laboratory factors. In support of this conclusion, previous research showed low rates of serious bacterial infections among older febrile infants classified as low-risk by the Rochester protocol, which recommends universal urine and blood testing but not universal CSF testing for this population.[6,7] We also did not detect a significant association between CPGs recommending universal CSF testing for older febrile infants and spending. However, diagnostic evaluations for febrile infants, particularly lumbar punctures, can cause physical and psychological stress to infants and their families.[20] The lack of association between these CPGs and improved clinical outcomes suggests that many families of older febrile infants could be spared the stress of CSF testing without harm.

Our findings have implications for research on low-value care. The majority of clinical services have both low-value and high-value applications.[21,22] As noted by the Institute of Medicine, a well-evaluated, reliable CPG can reduce low-value applications of clinical services.[23] Our study suggests that CPGs may also encourage low-value

applications of services without increasing their high-value applications, highlighting the importance of frequently re-evaluating CPG recommendations using the best available evidence.

Although we used a quasi-experimental design to control for unobserved differences between comparison groups that did not vary with age, we could not control for unobserved differences that did change with age, including severity of illness. This potential source of bias would be more likely, however, if there were differences in observed characteristics between comparison groups among older febrile infants that were not predicted by the corresponding differences among younger febrile infants. While these differences existed for a few characteristics we examined, they were small and paled in comparison to the differences for CSF testing.

Our study has other limitations. First, our analyses suggested that CPGs recommending universal CSF testing were associated with a $195 increase in spending, but our analysis lacked sufficient power to detect an increase of this magnitude. Second, estimates could be biased if the likelihood of readmission to a non-PHIS hospital differed between older febrile infants in the CPG and control groups. However, older febrile infants in each group were equally likely to be hospitalized following the initial ED visit, and results of a sensitivity analysis excluding hospitals with nearby competitors were not substantively different from the main results. Third, we may have underestimated the true number of adverse events due to our reliance on administrative data, though we would expect this potential bias to affect the comparison groups equally. Fourth, we relied on diagnosis codes to identify infants with fevers. While this strategy may have led to the inclusion of infants without fevers into our sample, results were substantively

unchanged in sensitivity analyses using alternative sample identification strategies. Finally, our sample was derived from large, tertiary pediatric hospitals. As such, our findings may not generalize to other types of hospitals and primary care settings.

CONCLUSION

In this study of U.S. children's hospitals, CPGs recommending universal CSF testing for older febrile infants were not associated with better clinical outcomes or lower spending. These CPGs may encourage applications of CSF testing that are not associated with clinical or economic benefits.

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Chapter 2: Changes in Health and Medical Spending among Young Adults under Health Reform

INTRODUCTION

Beginning on September 23, 2010, the Affordable Care Act (ACA) allowed young adults aged 19-25 to remain on their parent's private health insurance plan until age 26. In contrast to pre-existing state laws that had already extended dependent coverage eligibility, the ACA provision applied regardless of place of residence, marital status, or student status. In addition, the provision applied to self-insured employers. Existing plans with start dates before September 23, 2010 were exempted from the provision, but plans that started on or after this date were subject to the provision.[1,2]

Prior to implementation of the provision, approximately 32% of all young adults aged 19-25 were uninsured, the lowest coverage rate of any age group in the U.S.[3] Recent studies indicate that the provision was associated with improvements in insurance coverage and health care access in this population.[3-5] For example, Sommers *et al* found that the dependent coverage provision was associated with a 6.7 percentage point increase in the rate of insurance among young adults 19-25 between September 2010 and September 2011. The provision was also associated with a decreased likelihood of experiencing cost-related barriers to accessing health care.[3]

A number of important policy questions remain unanswered. First, it is unclear how the provision affected health care utilization among young adults. An analysis by the Health Care Cost Institute found that utilization of outpatient visits, inpatient admissions, emergency room visits, and mental health visits increased in 2011-2012 among young adults aged 19-25 with employer-based insurance, the population most

affected by the dependent coverage provision.[6] In contrast, another study found decreased use of the emergency department in New York, California, and Florida following implementation of the provision among young adults.[7] Furthermore, two analyses of national data found no association between implementation of the dependent coverage provision and utilization of preventive care such as routine checkups or flu shots among young adults.[7-9]

Second, it is unclear whether the provision improved the health of young adults. Several analyses of national data have found an association between implementation of the provision and improved self-reported overall health among young adults.[9-11] However, a study of national trauma registry data did not find changes in trauma-related mortality among young adults following implementation of the provision.[12] To date, no study has specifically assessed the effect of the provision on self-reported mental health.

Finally, it is unclear how the provision impacted health care expenditures among young adults. The Health Care Cost Institute analysis suggested that overall expenditures in 2011-2012 increased among young adults aged 19-25 with employer-sponsored insurance, but it is unclear whether these changes are attributable to the provision due to the descriptive nature of this analysis.[6] Previous research indicates that the provision also improved overall financial protection against the costs of medical care among young adults, but the measures of financial protection used in these studies had limitations. Mulcahy *et al* found a significant increase in the proportion of non-discretionary emergency department visits by young adults covered by private insurance following implementation of the provision. However, the authors could not assess out-of-pocket spending or financial protection against the costs of care outside of the emergency

department.[13] Busch *et al* found that implementation of the provision was associated with a small decrease in the proportion of young adults with annual out-of-pocket spending greater than $1,500, but this study did not analyze the effects of the provision on overall out-of-pocket spending.[14]

In this study, we assessed the impact of the ACA dependent coverage provision on health care utilization, self-reported physical and mental health, health care expenditures, and financial protection against health care costs among young adults aged 19-25. Based on previous research, we hypothesized that the provision increased use of outpatient care, improved self-reported physical and mental health, increased health care expenditures, and improved financial protection against health care costs among young adults.

METHODS

Study design

We conducted a difference-in-differences analysis, in which we estimated changes associated with the provision by comparing the difference in outcomes between the pre-intervention and post-intervention treatment group with the corresponding difference in the control group. We defined the treatment group as adults aged 19-25 and the control group as adults aged 26-34. Individuals in these age groups share many of the same health needs and face similar challenges in the health insurance market. For this reason, similar age-based comparisons have been used in other research on the effects of the provision.[4,5] We defined the pre-intervention period as 2002-2009 and the post-intervention period as 2011-2012, excluding 2010 as a washout period since many

existing insurance plans were unaffected by the provision until they renewed on January 1, 2011.[2]

Data source

We analyzed the 2002-2009 and 2011-2012 Medical Expenditure Panel Survey (MEPS), an annual survey conducted by the Agency for Healthcare Research and Quality that collects extensive information on health, health care utilization, and health care expenditures among the non-institutionalized U.S. civilian population. The sampling unit is the household, and one respondent answers questions on behalf of all other household members. Respondents are interviewed five times over the course of two years.[15] Because the MEPS contains publicly available, de-identified data, the Institutional Review Board at Harvard School of Public Health deemed this study exempt from review.

Study sample

We included all individuals aged 19-34 with positive survey weights in the 2002-2009 and 2011-2012 MEPS, defining age as estimated age on September 23 of the data year. These individuals provided a total of 69,502 person-years of data. We excluded 451 observations (0.64%) due to missing data for covariates (U.S. Census region and/or residence in a Metropolitan Statistical Area), leaving a total of 69,051 observations for the main sample. For analyses of self-reported health, we excluded an additional 543 observations (0.79%) due to missing outcome data. The principal group of interest, the post-intervention treatment group, contained 6,180 observations.

Study variables

Insurance outcomes were being insured, privately insured, and publicly insured at the end of the calendar year. Utilization outcomes were reporting at least one outpatient visit, primary care visit, emergency department visit, hospitalization, and prescription medicine fill in the prior 12 months. We defined an "outpatient visit" as an in-person, non-telephone visit to a physician or allied health professional in an office or hospital outpatient department. We defined a "primary care visit" as an outpatient visit to a physician with specialty training in internal medicine, family practice, general practice, pediatrics, or osteopathy.

Health outcomes were reporting excellent versus less-than-excellent physical health and reporting excellent versus less-than-excellent mental health. At the end of each survey interview round, respondents rated their physical and mental health on a five-point scale (1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent); we defined excellent health as a mean response over the year greater than 4.5.

To evaluate changes in health care expenditures, we assessed total annual health care expenditures (out-of-pocket plus insurance payments), annual out-of-pocket health care expenditures, and the percent of annual health care expenditures paid out-of-pocket among individuals with any annual expenditures. We used the general Consumer Price Index to adjust health care expenditures to 2012 levels.[16]

Statistical Analysis

For binary outcomes, we fitted linear probability models predicting the outcome as a function of treatment group status (ages 19-25 vs. 26-34), post-intervention year status (2011-2012 vs. 2002-2009), and their interaction (the difference-in-differences

estimate). We used linear models to facilitate straightforward interpretation of the interaction term, following the recommendations of previous studies.[17]

The distribution of health care expenditures in our sample was right-skewed because a substantial proportion of individuals had no expenditures. As such, we modeled annual health care expenditures and annual health care out-of-pocket expenditures using a two-part generalized linear model.[18] We first fitted a linear regression model predicting the probability of having any annual expenditures, then fitted a generalized linear model with a log link and gamma family variance function predicting expenditures among individuals with positive annual expenditures. Similarly, we fitted a linear regression model predicting the probability of having any out-of-pocket annual expenditures, then fitted a generalized linear model with a log link and Poisson family variance function predicting out-of-pocket expenditures among individuals with positive out-of-pocket expenditures. We chose variance functions for generalized linear models based on the modified Park test.[18] To improve the interpretability of results, we retransformed estimates from generalized linear models to the dollar scale using a simulation procedure (Appendix 2.1).

In all regressions, we controlled for gender, self-reported race/ethnicity, marital status, U.S. Census Region, and residence in a Metropolitan Statistical Area (urban/rural). In addition, we adjusted for the complex survey design of the MEPS by using sampling weights and robust design-based variance estimators.[19] In our main analysis, we did not control for socioeconomic status indicators such as family income, since this variable includes parental income for young adults living with their parents but does not include parental income for young adults living independently. In addition, we did not control

for number of years of education because the effects of education on the outcomes of interest vary between treatment groups (e.g., having a high school degree is the norm for 19 year-olds but may predict low socioeconomic status and poor health among 34 year-olds).

Our difference-in-differences analysis relied on the assumption that differences in outcomes between the treatment and control groups would have been the same before and after the 2010 in the absence of the provision. To evaluate this assumption, we compared pre-intervention trends in outcomes between groups by analyzing data from the 2002-2009 MEPS, fitting linear regression models or two-part models predicting outcomes as a function of treatment group status, year, and their interaction. In addition, we used linear regression to assess the existence of differential changes in observed demographic characteristics between the treatment and control groups before and after implementation of the provision. Differential changes in observed characteristics over time would suggest the possibility of bias from differential changes in unobserved characteristics.

We also performed a number of sensitivity analyses. First, we adjusted for any pre-existing diverging trends in regressions by allowing for a differential level and slope change in the post-intervention period (see Appendix 2.2 for more details). Second, we assessed whether results changed when we controlled for family income as a percentage of the federal poverty level and number of years of education. Finally, we redefined the control group as individuals aged 28-34 on September 23 of the data year, since 26-year olds in the 2011 MEPS and 27-year olds in the 2012 MEPS could have become insured under the dependent coverage provision when they were age 25.

We performed all analyses using SAS version 9.4 (Cary, NC), Stata SE 13.0, and R version 3.1.1. We considered two-sided p-values < 0.05 to indicate statistical significance.

RESULTS

Of 69,051 observations in the main sample, 38,848 were in the control group and 30,203 were in the treatment group. The demographic characteristics of the two groups were mostly similar, except the control group had a substantially higher proportion of married individuals and slightly higher proportions of females and whites (Table 2.1).

Figure 2.1 displays graphs of selected outcomes by year among the treatment and control groups, including insurance coverage, self-reported physical and mental health, annual out-of-pocket health care expenditures, and percent of annual health care expenditures paid out-of-pocket. Compared with the control group, the probability of having any health insurance coverage or private insurance coverage at the end of the year increased by 7.6 and 8.7 percentage points among young adults aged 19-25 after implementation of the provision, respectively ($p < 0.001$ for both estimates). However, the probability of having public insurance coverage at the end of the year did not significantly change (Table 2.2).

For the five types of utilization examined, the provision was not associated with significant changes in the probability of reporting at least one utilization event in the prior 12 months among young adults aged 19-25, compared with the control group. Compared with the control group, the probability of reporting excellent physical health increased by 4.9 percentage points among young adults aged 19-25 after implementation of the provision (unadjusted pre-intervention mean: 23.3%; $p < 0.001$). The probability of

reporting excellent mental health increased by 3.9 percentage points (unadjusted pre-intervention mean: 33.7%; p = 0.005) (Table 2.2).

The provision was not associated with a significant change in the probability of having any annual health care expenditures among young adults aged 19-25, compared with the control group. In addition, the provision was not associated with a statistically significant change in total annual health care expenditures among young adults aged 19-25 with any expenditures, compared with the control group. Among young adults aged 19-25 with any out-of-pocket expenditures, annual out-of-pocket expenditures decreased $79 per year compared with the control group (p = 0.03). After implementation of the provision, the mean percent of health care expenditures paid out-of-pocket decreased by 3.7 percentage points among young adults aged 19-25 with any annual expenditures, compared with the control group (unadjusted pre-intervention mean: 34.1%; p = 0.001) (Table 2.2).

Treatment and control groups had similar linear pre-intervention trends for all outcomes except for self-reported excellent physical health (difference in slope: 0.54 percentage points per year, p = 0.04) (Table 2.3). The trend-adjusted difference-in-differences estimate for this outcome was +1.3 percentage points (p = 0.28) (Table 2.4). Though this finding suggests that we may have overestimated the association between the provision and self-reported physical health, we note that the positive direction of the trend-adjusted estimate still supported our conclusions (see Appendix 2.2 for further discussion of the trend-adjusted results).

There were statistically significant differential changes in several observable characteristics such as the percentage of whites, Hispanics, Asians, married individuals,

individuals from the Midwest and South, and individuals living in urban areas (Table 2.5). However, the magnitudes of these differential changes were small (< 5.2 percentage points), supporting the validity of the underlying assumption of our approach. In other sensitivity analyses, results were substantively unchanged when we controlled for family income and education or excluded individuals aged 26-27 from the control group (Table 2.4).

Table 2.1. Demographic characteristics of the study sample

Demographic characteristic (%)	Control group (n = 38,848)	Treatment group (n = 30,203)
GENDER		
Female	54.2	51.9
RACE		
White	42.6	40.5
Hispanic	33.0	32.7
Black	15.9	18.6
Asian	6.2	5.2
Other	2.3	3.0
MARITAL STATUS		
Married	54.9	17.1
REGION		
Northeast	13.7	14.3
Midwest	19.3	19.2
South	37.5	38.3
West	29.4	28.1
URBAN/RURAL		
Urban	85.9	85.0

Table 2.2. Impact of dependent coverage provision on insurance coverage, utilization, self-reported health, overall health care expenditures, and out-of-pocket expenditures

OUTCOME	Treatment group		Control group		Estimate of Policy Impact (Adjusted Difference)		
	Pre-intervention mean	Post-intervention mean	Pre-intervention mean	Post-intervention mean	Estimate[a]	95% CI	P value
Insurance Coverage at the End of the Year							
Any health insurance	72.5%	70.9%	62.7%	68.9%	7.6	5.0, 10.3	<0.001
Private insurance	64.6%	61.0%	51.9%	57.2%	8.7	5.8, 11.7	<0.001
Public insurance	8.7%	11.3%	12.1%	13.5%	-1.2	-2.7, 0.3	0.11
Health Care Utilization in the Prior 12 months							
≥ 1 outpatient visit	63.8%	62.8%	57.1%	55.6%	-0.7	-3.3, 1.9	0.61
≥ 1 primary care physician visit	38.4%	36.6%	32.9%	31.7%	0.5	-2.3, 3.3	0.73
≥ 1 emergency department visit	12.8%	12.5%	15.0%	15.0%	0.3	-1.6, 2.2	0.75
≥ 1 hospitalization	7.6%	7.7%	6.1%	5.7%	-0.7	-1.9, 0.5	0.27
≥ 1 prescription medicine fill	54.7%	53.4%	49.2%	46.4%	-1.7	-4.2, 0.9	0.21
Self-Reported Health Status							
Excellent physical health	23.3%	21.5%	26.9%	29.9%	4.9	2.3, 7.4	<0.001
Excellent mental health	34.9%	33.7%	36.6%	39.4%	3.9	1.2, 6.6	0.005
Overall Health Care Expenditures							
Any annual expenditures	77.1%	75.3%	72.2%	70.5%	-0.1	-2.2, 2.1	0.95
Annual expenditures[b]	$3131	$3922	$2417	$2956	-0.014	-0.33, 0.30	0.93
Out-of-Pocket Health Care Expenditures							
Any annual out-of-pocket expenditures	72.0%	69.0%	65.7%	62.0%	-0.9	-3.3, 1.6	0.49
Annual out-of-pocket expenditures[c]	$642	$657	$559	$488	-0.16	-0.31, -0.02	0.03
Percent of expenditures paid out-of-pocket[d] (%)	31.9%	34.1%	34.4%	32.8%	-3.5	-5.8, -1.2	0.003

[a]Estimates report the adjusted coefficient of the interaction between post-intervention status and treatment group. For all outcomes other than annual expenditures and annual out-of-pocket expenditures, estimates represent absolute percentage point changes. For continuous expenditure outcomes, estimates have a ratio-of-ratios interpretation.
[b]Among individuals with non-zero annual expenditures (n=47,402).
[c]Among individuals with non-zero annual out-of-pocket expenditures (n=42,355).
[d]Among individuals with non-zero annual health care expenditures

Table 2.3. Comparison of pre-intervention outcome trends in treatment and control groups

OUTCOME	Estimate[a]	P value
Insurance Coverage at the End of the Year		
Any health insurance	0.41	0.11
Private insurance	0.44	0.10
Public insurance	-0.06	0.68
Health Care Utilization in the Prior 12 months		
≥ 1 outpatient visit	-0.24	0.30
≥ 1 primary care physician visit	0.08	0.73
≥ 1 emergency department visit	-0.01	0.94
≥ 1 hospitalization	-0.04	0.71
≥ 1 prescription medicine fill	-0.07	0.76
Self-Reported Health Status		
Excellent physical health	0.54	0.04
Excellent mental health	0.23	0.43
Overall Health Care Expenditures		
Any annual expenditures	0.20	0.32
Total annual expenditures	0.00	0.78
Out-of-Pocket Health Care Expenditures		
Any annual out-of-pocket expenditures	0.04	0.84
Total annual out-of-pocket expenditures	0.00	0.62
Percent of expenditures paid out-of-pocket (%)	-0.12	0.55

[a]Estimates represent the difference in the slopes of pre-intervention outcome trends between treatment and control groups. For all outcomes other than annual expenditures and annual out-of-pocket expenditures, estimates represent absolute percentage point changes. For expenditure outcomes, estimates have a ratio-of-ratios interpretation.

Table 2.4. Results of sensitivity analyses

OUTCOME	Adjust for pre-existing trends			Control for socioeconomic status			Exclude ages 26-27		
	Estimate[a]	95% CI	P value	Estimate[a]	95% CI	P value	Estimate[a]	95% CI	P value
Insurance Coverage at End of the Year									
Any health insurance	4.7	2.1, 7.4	<0.001	8.2	5.5, 10.9	<0.001	7.5	4.8, 10.3	<0.001
Private insurance	4.8	2.1, 7.5	<0.001	9.6	6.8, 12.4	<0.001	8.7	5.6, 11.7	<0.001
Public insurance	2.5	-1.7, 2.2	0.81	-1.6	-3.2, -0.1	0.04	-1.0	-2.7, 0.6	0.20
Health Care Utilization in the Prior 12 months									
≥ 1 outpatient visit	1.6	-1.1, 4.2	0.25	-0.3	-3.2, 2.6	0.83	-1.1	-3.7, 1.5	0.42
≥ 1 primary care physician visit	2.0	-0.6, 4.6	0.13	2.4	-0.8, 5.6	0.15	0.3	-2.6, 3.3	0.82
≥ 1 emergency department visit	1.0	-0.9, 3.0	0.31	0.1	-1.9, 2.2	0.89	-0.5	-2.5, 1.4	0.60
≥ 1 hospitalization	-0.8	-0.2, 0.6	0.27	-0.7	-2.1, 0.8	0.35	-0.9	-2.2, 0.3	0.15
≥ 1 prescription medicine fill	-0.4	-3.0, 0.2	0.79	-1.4	-4.3, 1.5	0.34	-2.1	-4.8, 0.6	0.13
Self-Reported Health Status									
Excellent physical health	1.3	-1.1, 3.7	0.28	6.0	3.1, 8.9	<0.001	5.0	2.3, 7.8	<0.001
Excellent mental health	1.3	-1.4, 3.9	0.35	4.1	1.0, 7.3	0.01	3.9	0.9, 6.9	0.01
Overall Health Care Expenditures									
Any annual expenditures	-0.6	-3.1, 1.8	0.62	-0.2	-2.6, 2.2	0.89	-0.3	-2.5, 1.9	0.80
Annual expenditures[b]	-0.04	-0.40, 0.32	0.82	-0.08	-0.39, 0.24	0.24	-0.04	-0.38, 0.30	0.82
Out-of-Pocket Health Care Expenditures									
Any annual out-of-pocket expenditures	0.2	-2.4, 2.8	0.13	-0.0	-2.6, 2.6	1.00	-1.2	-3.7, 1.3	0.35
Annual out-of-pocket expenditures[c]	-0.18	-0.18, -0.17	<0.001	-0.15	-0.33, 0.02	0.08	-0.16	-0.31, -0.02	0.03
Percent of expenditures paid out-of-pocket[b] (%)	-1.5	-3.6, 0.7	0.19	-3.4	-5.9, -0.9	0.008	-3.8	-6.1, -1.5	0.001

[a]Estimates report the adjusted coefficient of the interaction between post-intervention status and treatment group. For all outcomes other than annual expenditures and annual out-of-pocket expenditures, estimates represent absolute percentage point changes. For continuous expenditure outcomes, estimates have a ratio-of-ratios interpretation.

[b]Among individuals with non-zero annual expenditures.

[c]Among individuals with non-zero annual out-of-pocket expenditures.

Table 2.5. Differential change in observed demographic characteristics between treatment and control groups

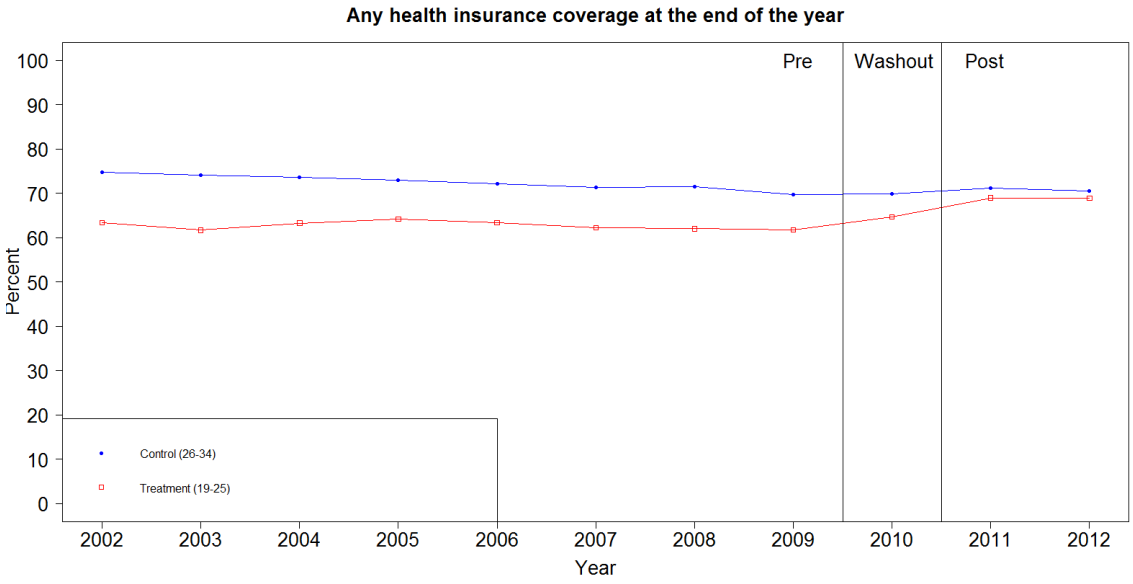
Demographic characteristic (%)	Pre-intervention control	Post-intervention control	Pre-intervention treatment	Post-intervention treatment	Difference-in-differences[a]	P value[a]
GENDER						
Female	54.2	54.3	52.1	51.3	-0.9	0.34
RACE						
White	44.0	37.7	42.9	32.4	-4.2	<0.001
Hispanic	33.0	32.9	32.0	35.3	3.4	<0.001
Black	15.0	18.8	17.5	22.5	1.2	0.08
Asian	5.6	8.4	4.7	6.7	-0.8	0.05
Other	2.4	2.1	2.9	3.2	0.5	0.07
MARITAL STATUS						
Married	57.1	47.1	18.2	13.4	5.2	<0.001
REGION						
Northeast	13.3	15.4	13.8	16.2	0.3	0.62
Midwest	19.2	19.7	19.8	17.4	-2.9	<0.001
South	38.0	35.8	38.0	39.3	3.4	<0.001
West	29.5	29.1	28.4	27.1	-0.9	0.31
URBAN/RURAL						
Urban	85.1	88.5	83.7	89.5	2.4	<0.001

[a]We fitted a linear probability model predicting each characteristic as a function of treatment group status, post-intervention period status, and its interaction. The difference-in-differences estimate and p values refer to the coefficient and significance of the interaction term, respectively.

Figure 2.1. Unadjusted Trends in Insurance Coverage, Self-Reported Health, and Expenditures among Young Adults. A) Percent with any health insurance coverage at the end of the year; B) Percent reporting excellent physical health; C) Percent reporting excellent mental health; D) Annual out-of-pocket health care expenditures (among individuals with any annual out-of-pocket expenditures); E) Percent of annual health care expenditures paid out-of-pocket (among individuals with any annual expenditures).

Figure 2.1, continued

A.



B.

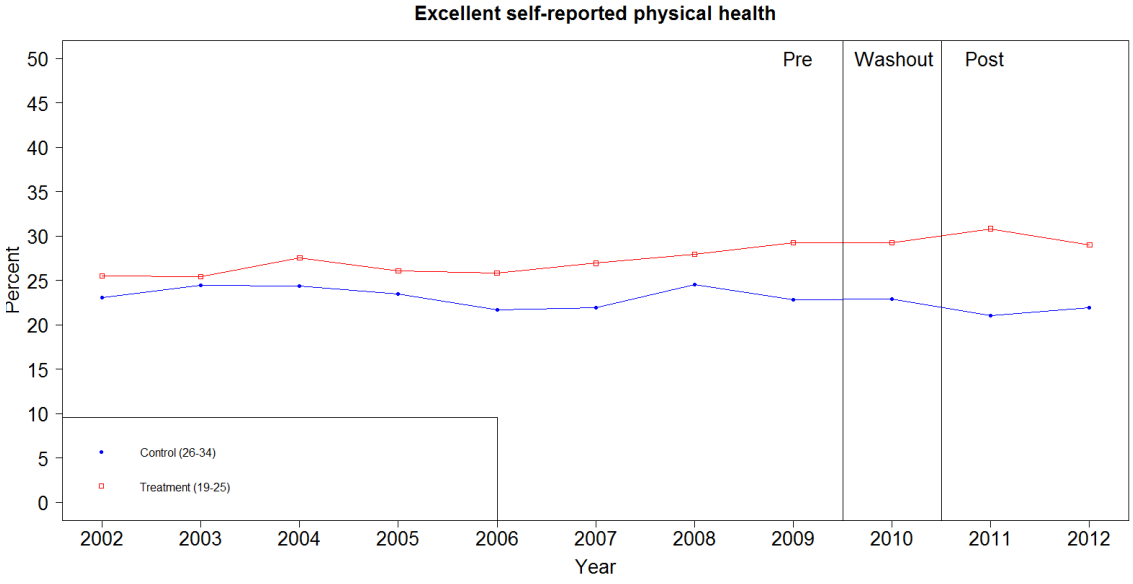
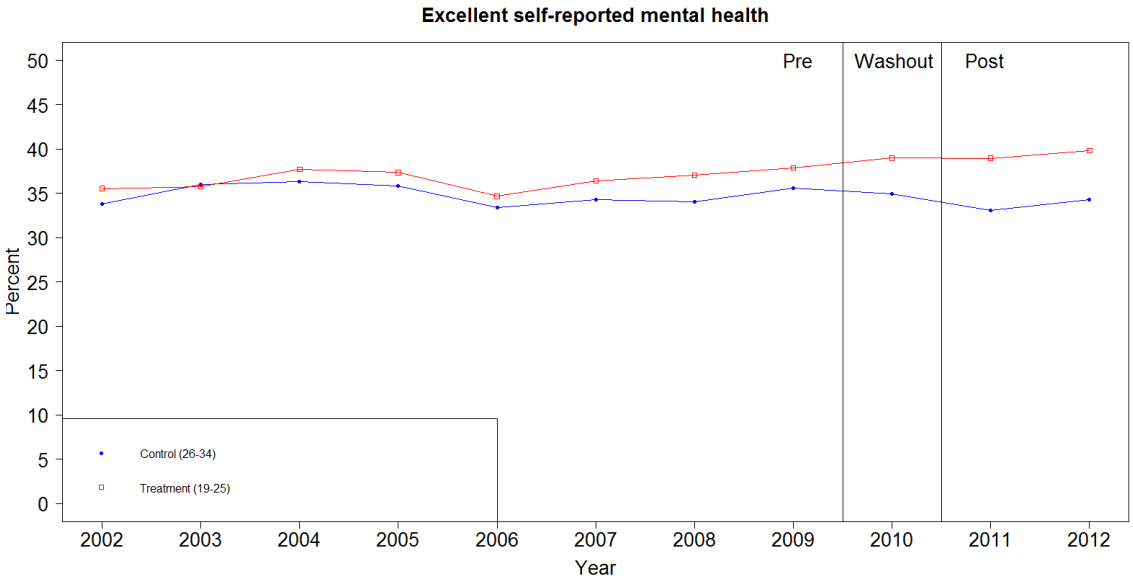


Figure 2.1, continued

C.



D.

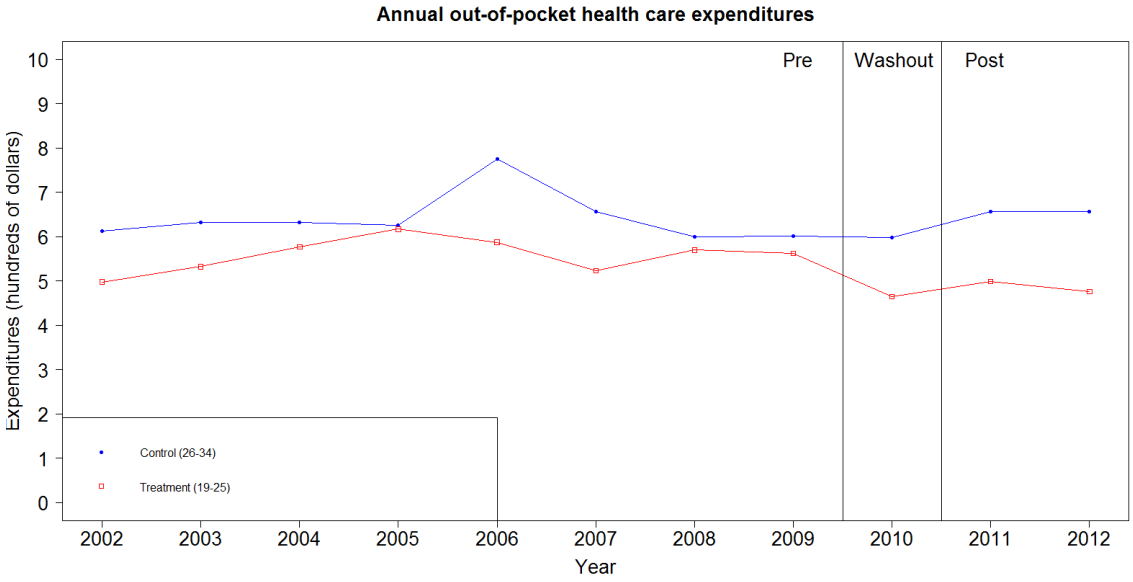
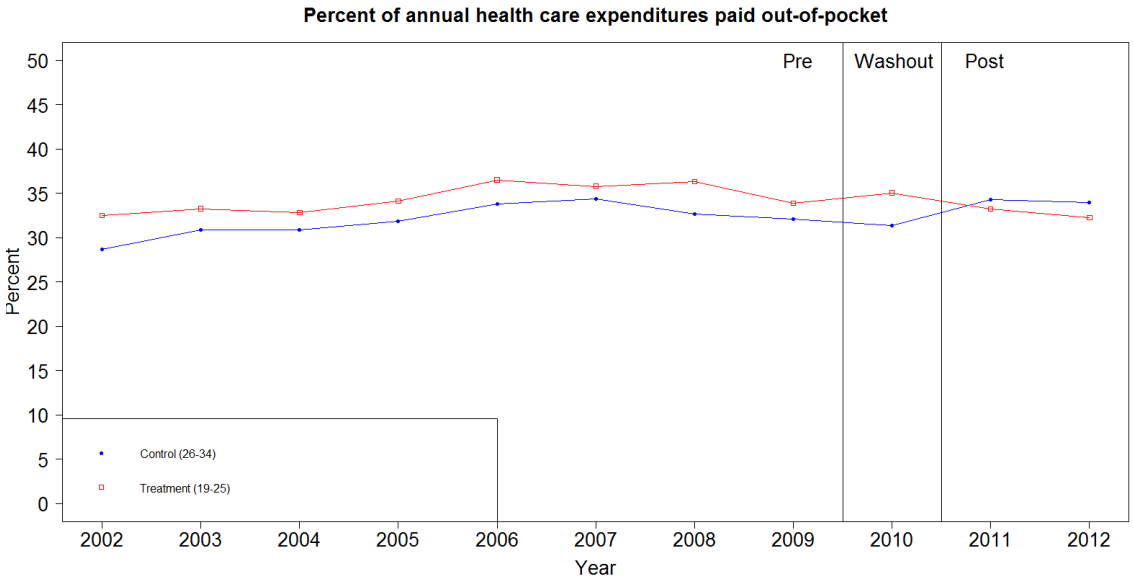


Figure 2.1, continued

E.



DISCUSSION

Using a nationally representative survey and a quasi-experimental approach, we analyzed changes in health care utilization, self-reported health, and health care expenditures among young adults aged 19-25 after implementation of the ACA dependent coverage provision. We found that the provision was associated with improved self-reported physical and mental health as well as increased financial protection against health care costs in this population.

The improvements in self-reported physical and mental health following implementation of the provision are consistent with prior research on the provision as well as with research showing improved self-reported health among previously uninsured low-income and elderly adults who gained insurance coverage.[9,10,20,21] Specifically, we detected a significant reduction in the proportions of young adults aged 19-25 reporting less-than-excellent physical health and less-than-excellent mental health. The exact mechanism of these improvements is unclear. One possibility is that gaining insurance coverage improved young adults' sense of security and well-being, thus enhancing perception of their physical and mental health. In support of this latter possibility, a study examining the effects of gaining Medicaid coverage among low-income adults in Oregon showed that improvements in self-reported health occurred almost immediately after becoming insured and before any increases in health care utilization.[20] This finding may raise the question of whether the gains in self-reported health in our study reflected gains in "actual" health.[22] However, previous research suggests that self-reported physical health correlates well with objective health measures, while mental health is assessed based on self-report.[20,23]

Implementation of the dependent coverage provision was not associated with significant changes in annual health care expenditures among young adults aged 19-25 years, but it was associated with substantial improvements in financial protection against medical costs in this population, as evidenced by decreased annual out-of-pocket health care expenditures and a decrease in the percent of annual health care expenditures paid out-of-pocket. These findings are consistent with a large body of literature showing improved financial protection against medical costs after insurance coverage expansions[20], as well as with research showing a reduction in cost-related access barriers and high out-of-pocket spending among young adults after implementation of the provision.[3,14]

Unlike previous studies on the effects of insurance coverage gains among previously uninsured low-income and near-elderly adults, we did not find that implementation of the dependent coverage provision was associated with significant changes in health care utilization among young adults aged 19-25.[20,24] Due to limited statistical power, however, we cannot be certain that there was no change in utilization after implementation of the provision. If the lack of a detected effect represents a true null finding, potential explanations include the existence of other access barriers or the lack of perceived need to seek health care, the latter of which may be especially relevant for our study's generally healthy population.[25]

There are a number of other limitations to our study. First, we lacked sufficient statistical power to identify which subgroups differentially benefited from the provision. Second, we cannot exclude the possibility that other events during the post-intervention period differentially affected outcomes in the treatment and control groups. Most

notably, a number of other ACA provisions took effect on September 23, 2010, including provisions that prevented insurers from rescinding coverage for individuals when they became sick, eliminated lifetime limits on insurance coverage, and required coverage of certain types of preventive care.[26] However, these provisions applied to both the treatment and control groups, and it is unlikely that they had a differential impact large enough to explain our findings.

CONCLUSION

In this analysis of nationally representative data, we found that implementation of the ACA dependent coverage provision was associated with significant improvements in self-reported health and financial protection against health care costs among young adults aged 19-25. Our study highlights the importance of expanding insurance coverage in this population and adds to a growing literature demonstrating that coverage expansions – whether via public or private coverage, and whether among older or younger adults – are associated with rapid improvements in financial protection and perceptions of health. Future research will be needed to determine whether our findings generalize to young adults aged 19-25 years who gain insurance coverage under the ACA through Medicaid eligibility expansions and Health Insurance Marketplaces.

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Chapter 3: Differences in Health Care Access and Utilization between Older Adolescents and Young Adults with Asthma

INTRODUCTION

As adolescents transition to young adulthood, they often experience changes that could affect their health care utilization, including discontinuation of schooling and transitions to independent living.[1,2] Many young adults also lose health insurance coverage. Medicaid and the Children's Health Insurance Program (CHIP) cover individuals aged 18 and younger in low-income families but generally do not cover individuals aged 19 and older unless they are pregnant, are disabled, or have children.[3] Furthermore, prior to a recently implemented provision of the Affordable Care Act (ACA), private insurance policies in most states did not cover dependents older than age 18 unless they were full-time students.[3] Consequently, individuals aged 19-25 had the highest uninsurance rate of any age group in 2010.[4]

Previous research suggests that the health care access and utilization patterns of young adults may be suboptimal.[5,6] Compared to adolescents, young adults use less primary care and rely more heavily on emergency departments (EDs) for care.[7] Whether these differences exist between adolescents and young adults with chronic diseases is unknown.

Using nationally representative survey data, we assessed differences in access and utilization between older adolescents and young adults with asthma. Asthma is highly prevalent in these age groups,[8,9] and exacerbations may lead to emergent care when asthma is not appropriately managed or when ambulatory care cannot be accessed.[10,11] We hypothesized that young adults with asthma are less likely than older adolescents with asthma to have a usual source of care, less likely to use primary and preventive care,

less likely to fill prescriptions for asthma medications, and more likely to use the ED. We also explored potential mediators of these differences, focusing on insurance coverage, a factor targeted by recent legislation.

METHODS

Data source

We analyzed data from the 1999-2009 Medical Expenditure Panel Survey (MEPS), a nationally representative panel survey that examines access and utilization in the U.S. civilian non-institutionalized population. Households are interviewed five times during the two-year survey period; one respondent answers for the entire household. A parent or adult relative usually provides proxy reports for adolescents and young adults living at home. In contrast, young adults living away at college and independently living young adults self-report information.[12]

Study design

In cross-sectional analyses, we compared several measures of access and utilization between older adolescents and young adults with asthma. In longitudinal analyses, we tested whether changes in insurance coverage, schooling, or adult presence at home predicted changes in these measures among individuals with asthma transitioning from adolescence to young adulthood.

Cross-sectional analysis

Study population

We included participants for whom a current diagnosis of asthma, an asthma-related utilization event, or an asthma-related disability day was reported. Using age on July 1, we classified participants aged 14-17 as older adolescents and participants aged

19-25 as young adults. We excluded participants aged 18 because age 18 is a transitional year during which changes in insurance coverage, schooling, and living situations often occur. Our aim was to compare outcomes before and after the bulk of these transitions occurred.

Study variables

Based on respondent reports of access and utilization over the prior 12 months, we constructed 8 dichotomous dependent variables for having: 1) a usual source of care; 2) ≥1 primary care visit; 3) ≥1 preventive visit; 4) ≥1 fill of a short-acting beta agonist (SABA) prescription; 5) ≥1 fill of a controller medication prescription; 6) ≥1 ED visit; 7) a cost or coverage-related problem accessing medical care; and 8) a cost or coverage-related problem accessing medications. For primary care visits, preventive visits, and cost or coverage-related access problems, we analyzed data from 2002-2009 because these items were not available prior to 2002.

We defined a usual source of care as a non-ED facility that participants usually visited when they were sick or needed health advice. We defined a primary care visit as an office visit to a physician whose specialty was family practice, general practice, internal medicine, osteopathy, or pediatrics. We defined a preventive visit as a primary care visit that respondents classified as a "general checkup."[13] Information on prescription fills was collected from respondent reports and pharmacies.[14] Controller medications included inhaled corticosteroids, leukotriene modifiers, and combinations of inhaled corticosteroids/long-acting beta agonists. We defined a cost or coverage-related access problem as a delay or inability to receive care due to unaffordability, denial of coverage by an insurance company, or refusal of insurance by a physician.[12]

Statistical analysis

To provide readily interpretable estimates in terms of absolute percentage differences, we fitted linear models predicting each dichotomous dependent variable as a function of age group (young adults vs. older adolescents), age in months (to adjust for trends preceding and continuing in young adulthood), race/ethnicity, gender, and survey year. To adjust for geographic variations, we included geographic identifiers at the level of metropolitan areas for densely populated areas and states or Census regions for less populated areas (based on strata of the MEPS survey design).

In separate models, we added the percentage of months spent uninsured in each survey year as a covariate to determine the degree to which differences in coverage explained differences in access and utilization between age groups.

Sensitivity analyses

We conducted 3 sensitivity analyses. First, because respondents were not asked if household members had a current diagnosis of asthma until 2003, we conducted an analysis that restricted our sample to participants classified as having asthma from reports of asthma-related utilization events or disability days. Second, we used logistic instead of linear regression models. Finally, to test whether differences between age groups were driven by inconsistencies between proxy and self-reports, we excluded participants who self-reported information the entire survey year.

Longitudinal Analysis

Study sample

For longitudinal analyses examining participants transitioning from adolescence to young adulthood, we restricted the sample to participants with asthma who were aged

16-19 at the beginning of survey participation and who provided data in both survey years.

Study variables

Because the small cohort size limited statistical power, we only analyzed 5 dichotomous dependent variables: reports of having a usual source of care and reports of having ≥1 primary care visit, preventive visit, fill of a SABA prescription, and fill of a controller medication prescription in the prior 12 months.

For our main predictors of interest, we created 3 variables describing changes in insurance coverage, schooling, and adult presence at home (defined as living with a parent or adult relative ≥35) between the first and second years of survey participation. To assess insurance loss, we subtracted the percentage of months insured in year 2 from the percentage of months insured in year 1 and truncated negative differences (due to the few who gained coverage) to zero. Thus, a unit increase in this variable indicated a change from continuous insurance coverage in year 1 to continuous uninsurance in year 2. To assess discontinued schooling, we constructed a similar variable from student status information reported during each interview. A unit increase in this variable indicated a change from continuous full-time schooling in year 1 to no schooling in year 2. To assess loss of adult presence at home, we created a similar variable from household structure information reported during each interview. A unit increase in this variable indicated a change from continuous adult presence at home in year 1 to continuous independent living in year 2. Student status is not determined for MEPS participants under age 17, but we assumed that adolescents aged 16 were full-time students because approximately 98% of the national population is enrolled in school at this age.[15]

Statistical analysis

We fitted linear regression models predicting access and utilization as a function of survey participation year (first vs. second), changes in insurance coverage, and the interaction between these terms (see Appendix 3.1 for model specification). The interactions estimated the differential changes in outcomes associated with coverage losses, relative to participants who experienced no coverage loss. To control for changes in schooling and adult presence at home, as well as to assess whether these social factors predicted access and utilization, we similarly included these changes and their interactions with survey participation year. Covariates included age at the beginning of year 1, race/ethnicity, gender, data year (MEPS panel), Census region, and, within each region, whether participants resided in a metropolitan area or not.

We performed analyses using SAS version 9.2 (Cary, NC). We adjusted for the complex survey design of the MEPS by employing sampling weights and using robust design-based variance estimators.[16] We considered two-sided p values < 0.05 to indicate statistical significance. The Committee on Human Studies at Harvard Medical School deemed this study exempt from review.

RESULTS

Cross-sectional analyses

After excluding 18 year-olds, 2,485 participants met inclusion criteria for analyses of 1999-2009 data, providing 3,469 person-years of data. 2,173 participants met inclusion criteria for analyses of 2002-2009 data, providing 2,958 person-years of data. For analyses of usual source of care and cost or coverage-related access problems, we excluded 0.5%-1.5% of observations due to missing data.

Older adolescents and young adults with asthma differed significantly by race/ethnicity, gender, and insurance coverage (Table 3.1). Figure 3.1 displays adjusted age-specific means and fitted regression lines for the 8 outcomes. Young adults with asthma were less likely to have a usual source of care than older adolescents with asthma (adjusted means: 65.5% vs. 79.2%; difference: -13.7 percentage points; P<0.001). In the prior 12 months, young adults were less likely to have ≥1 primary care visit (44.4% vs. 58.3%; difference: -13.9 percentage points; P=0.006) and ≥1 preventive visit (16.6% vs. 33.7%; difference: -17.1 percentage points; P<0.001). Young adults were also less likely to fill a SABA prescription at least once in the prior 12 months (34.7% vs. 45.3%; difference: -10.6 percentage points; P=0.02) but not significantly less likely to fill a controller medication prescription at least once in the prior 12 months.

Young adults with asthma were more likely to have ≥1 ED visit in the prior 12 months (28.5% vs. 18.5%; difference: +9.7 percentage points; P=0.01). They were also more likely to experience cost or coverage-related problems accessing medical care (8.1% vs. 3.3%; difference: +4.9 percentage points; P=0.01) and medications (5.4% vs. 1.9%; difference: +3.6 percentage points; P=0.04). Adjusting for differences in insurance coverage reduced differences in access and utilization by up to 61.1%, though the difference for ED visits did not change substantially (Table 3.2).

In sensitivity analyses, results of cross-sectional comparisons were not substantively changed by restricting the sample to participants for whom an asthma-related utilization event or disability day was reported, by using logistic instead of linear regression, or by excluding participants who self-reported information the entire survey

year (see Appendix 3.1 and Appendix 3.2 for additional analyses regarding potential response bias).

Longitudinal analyses

For longitudinal analyses of 1999-2009 data, 740 participants met inclusion criteria, yielding 1,480 person-years of data. We excluded at most 3.8% of observations due to missing data. For analyses of 2002-2009 data, 608 participants met inclusion criteria, yielding 1,216 person-years of data. We excluded 2.3% of observations due to missing data.

There were substantial differences between age groups in insurance coverage, schooling, and adult presence at home (Appendix Figure 3.1). Transitioning from continuous insurance coverage in year 1 to continuous uninsurance in year 2 was associated with a significant decrease in having a usual source of care in year 2 (change relative to no coverage loss: -25.2 percentage points; P=0.003). Transitioning from continuous full-time schooling in year 1 to no schooling in year 2 was associated with significant reductions in reports of ≥1 primary care visit (change relative to no change in schooling: -21.1 percentage points; P=0.03) and ≥1 preventive care visit (change relative to no change in schooling: -21.4 percentage points; P=0.02). Transitioning from continuous adult presence at home in year 1 to continuous independent living in year 2 was associated with a significant increase in reports of filling a SABA prescription at least once (change relative to no loss of adult presence at home: +20.9 percentage points; P=0.001) (Table 3.3).

Table 3.1. Demographic characteristics of study sample, MEPS 1999-2009.

	Older Adolescents (n = 1871)	**Young Adults (n = 1598)**	**P value**
Race			<0.001[a]
Asian/no other race/not Hispanic	2.1%	3.1%	
Black/no other race/not Hispanic	25.1%	22.3%	
Hispanic	24.5%	20.5%	
Other race/not Hispanic	48.4%	54.1%	
Gender			<0.001[a]
Female	47.0%	61.6%	
Insurance coverage			<0.001[b]
Percent of months uninsured	10.6%	33.5%	

[a]P value is derived from a chi squared test.
[b]P value is derived from a two-sample t-test assuming unequal variance.

Table 3.2. Differences in access and utilization between older adolescents and young adults with asthma, before and after adjustment for insurance coverage.

	Absolute difference between age groups, not adjusting for insurance coverage (percentage points)	**P value**	**Absolute difference between age groups, adjusting for insurance coverage (percentage points)**	**P value**	**Percent change in absolute difference between age groups after adjusting for insurance coverage (%)**
Usual source of care	-13.7	<0.001	-8.5	0.02	38.0
≥1 primary care visit	-13.9	0.006	-9.4	0.07	32.4
≥1 preventive visit	-17.1	<0.001	-15.0	0.001	12.3
≥1 fill of a short-acting beta agonist prescription	-10.6	0.02	-9.0	0.05	15.1
≥1 fill of a controller medication prescription	-5.3	0.19	-3.7	0.37	30.2
≥1 emergency department visit	9.7	0.01	8.7	0.03	10.3
Cost or coverage-related problem accessing medical care	4.9	0.01	2.6	0.14	46.9
Cost or coverage-related problem accessing medications	3.6	0.04	1.4	0.42	61.1

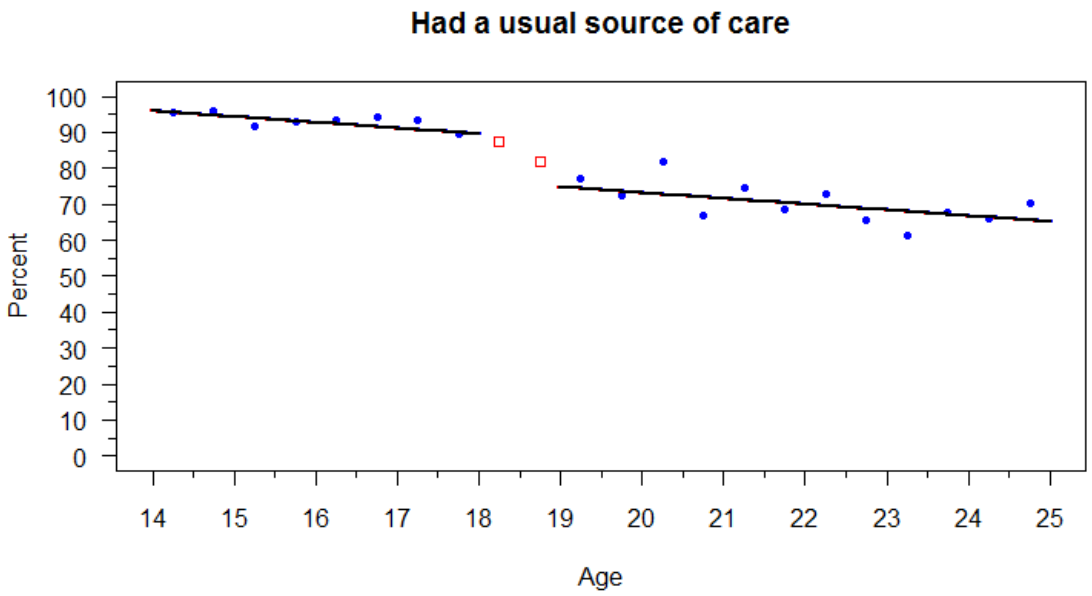
Table 3.3. Changes in health care access and utilization associated with changes in insurance coverage, schooling, and adult presence at home, among participants with asthma transitioning to young adulthood.

Year 2 – Year 1 absolute change in access or utilization measure	Access or utilization measure (percentage points)									
	Usual source of care		≥1 primary care visit		≥1 preventive visit		≥1 fill of a short-acting beta agonist prescription		≥1 fill of a controller medication prescription	
	Estimate	P value	Estimate	P value	Estimate	P Value	Estimate	P value	Estimate	P value
A. Participants with no change in insurance coverage, schooling, or adult presence at home	0.7	0.76	-5.1	0.12	3.4	0.41	-7.0	0.006	-2.2	0.29
B. Differential change for participants losing insurance coverage (vs. A)	-25.2	0.003	-9.0	0.30	-3.7	0.67	-2.3	0.78	-1.1	0.83
C. Differential change for participants discontinuing schooling (vs. A)	1.0	0.89	-21.1	0.03	-21.4	0.02	-10.2	0.16	-10.2	0.07
D. Differential change for participants losing adult presence at home (vs. A)	2.8	0.72	-2.1	0.83	-10.4	0.35	20.9	0.001	4.0	0.42

Figure 3.1. Health care access and utilization among older adolescents and young adults with asthma. Panels A-H display age-specific means and fitted regression lines for each of the 8 dependent variables in cross-sectional comparisons. The square data points represent excluded data for participants aged 18. A) Usual source of care; B) ≥1 primary care visit in the prior 12 months; C) ≥1 preventive visit in the prior 12 months; D) ≥1 fill of a short-acting beta agonist prescription in the prior 12 months; E) ≥1 fill of a controller medication prescription in the prior 12 months; F) ≥1 emergency department visit in the prior 12 months; G) Cost or coverage-related problem accessing medical care in the prior 12 months; H) Cost or coverage-related problem accessing medications in the prior 12 months.

Figure 3.1, continued

A.



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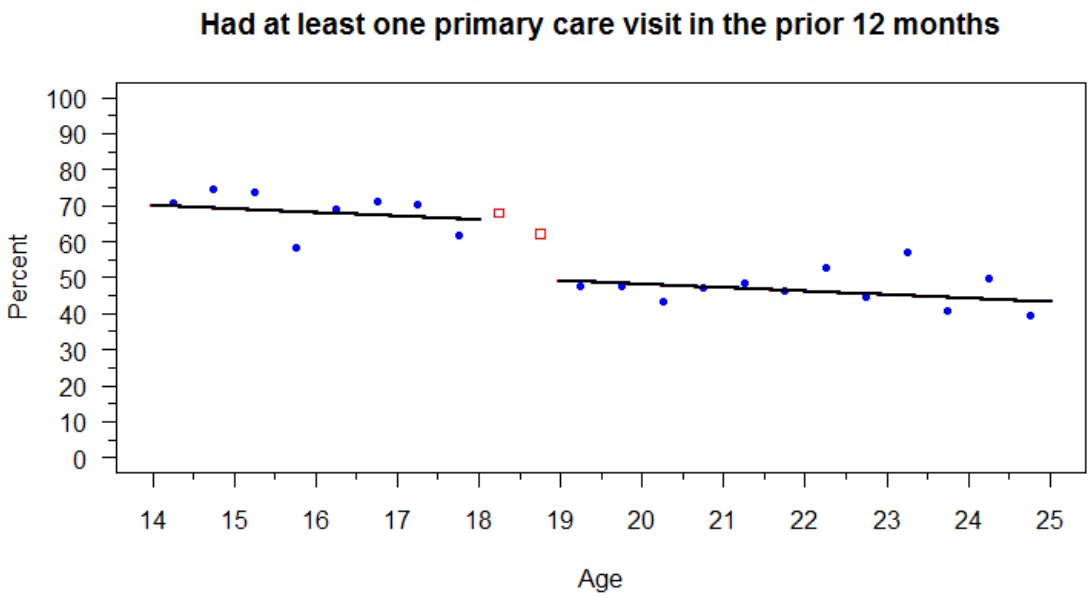
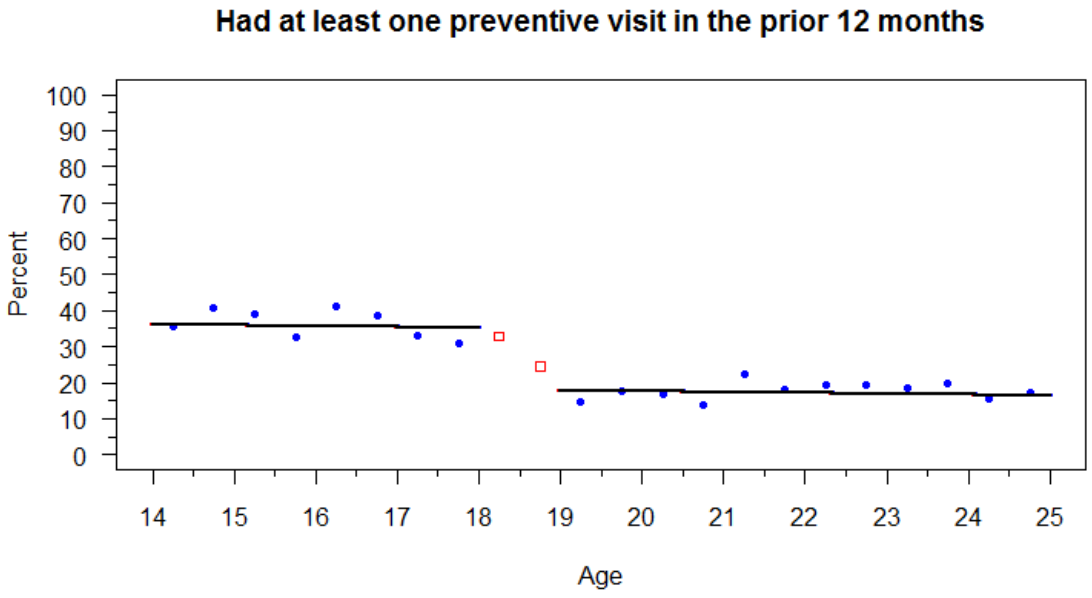


Figure 3.1, continued

C.



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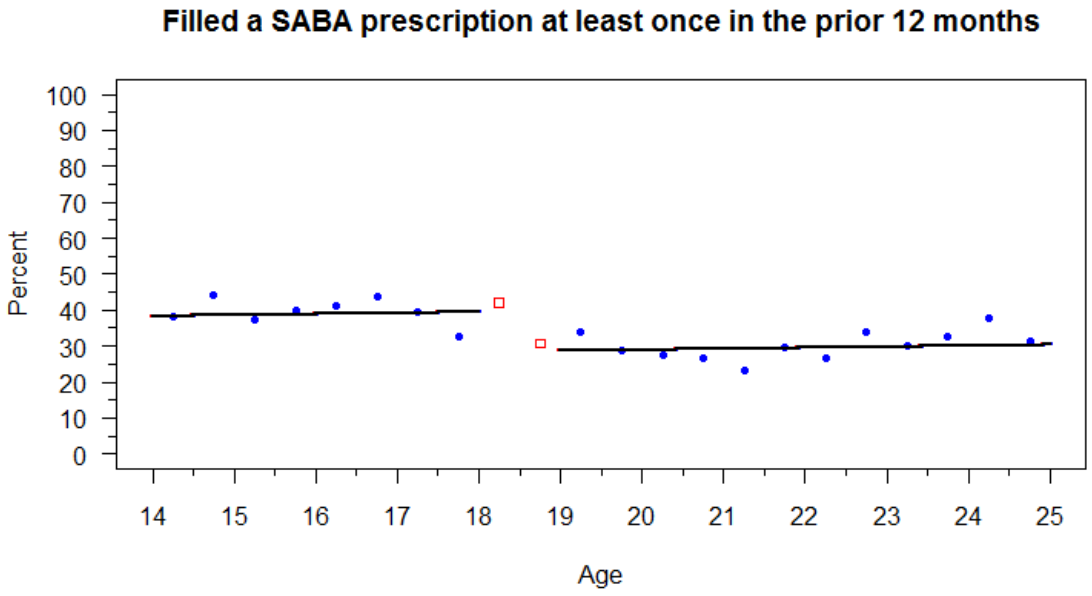
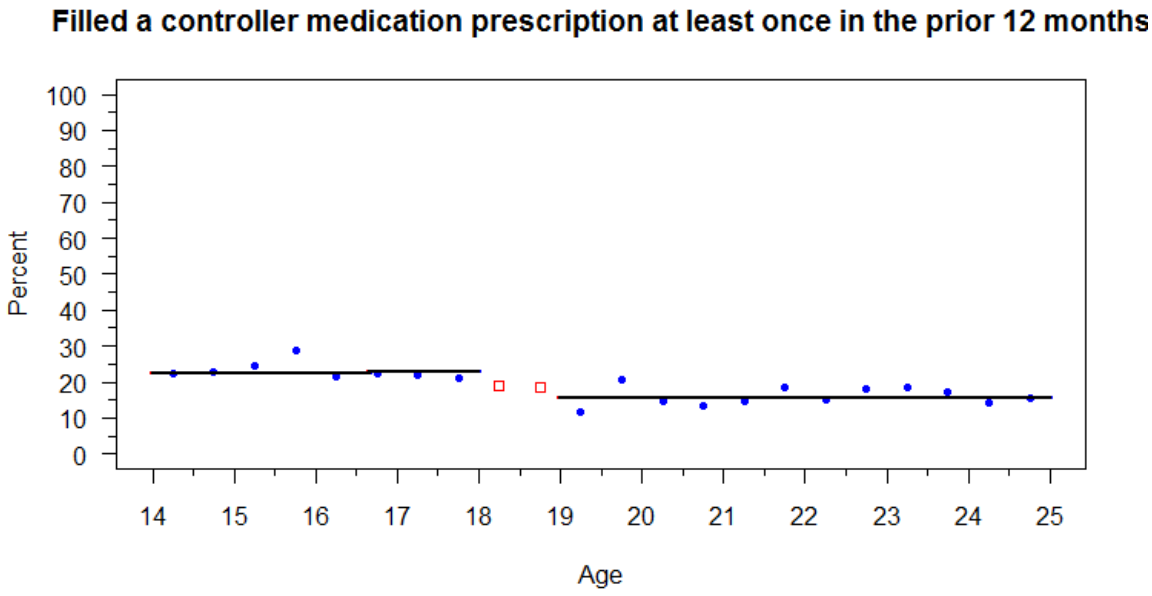


Figure 3.1, continued

E.



F.

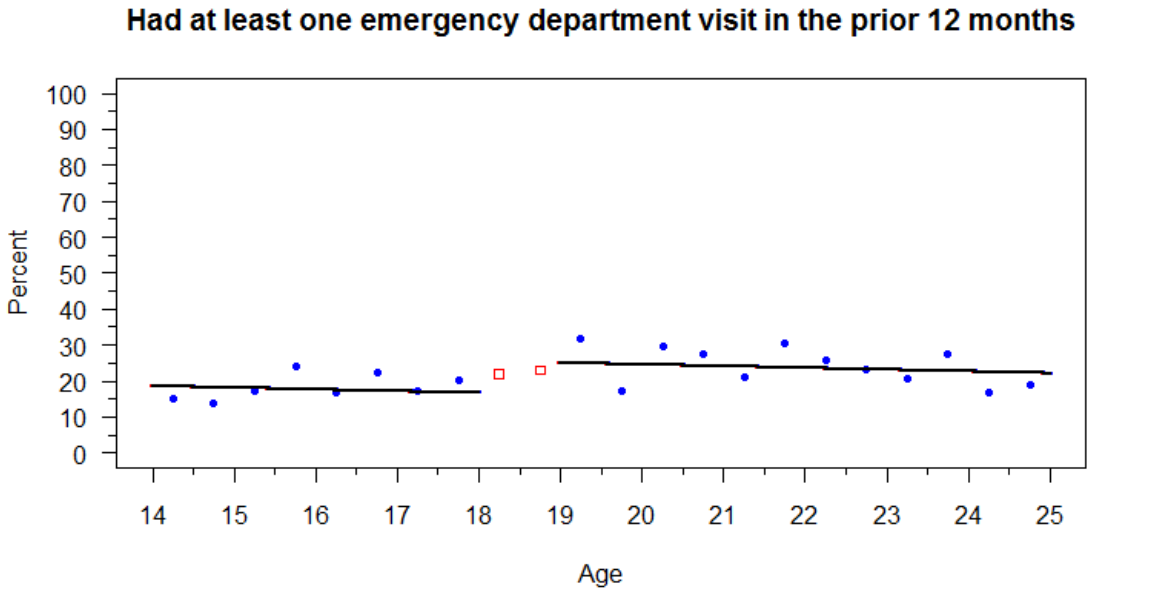
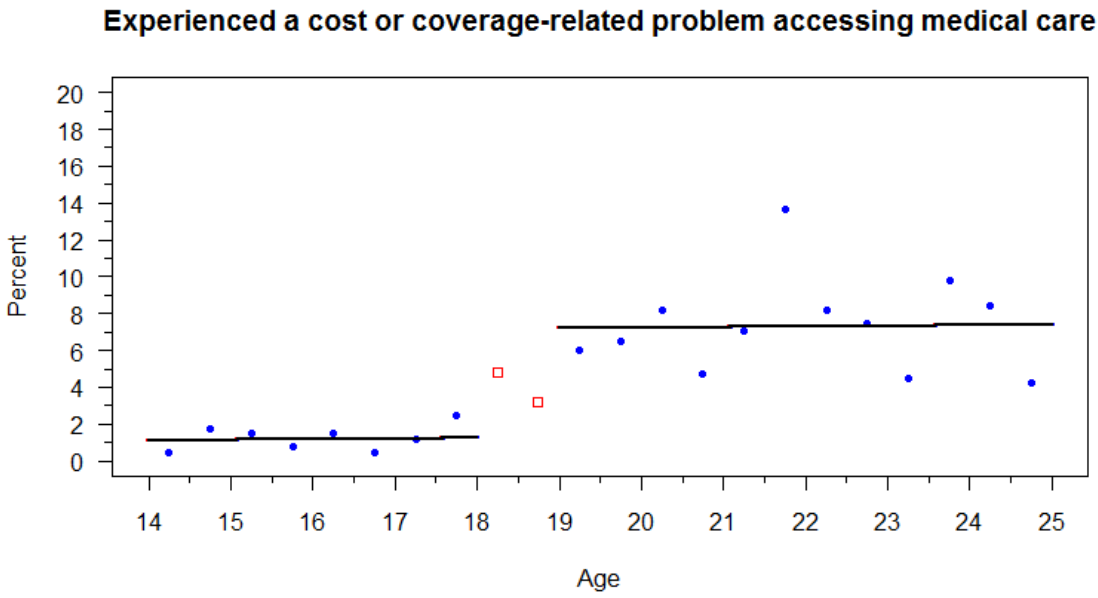
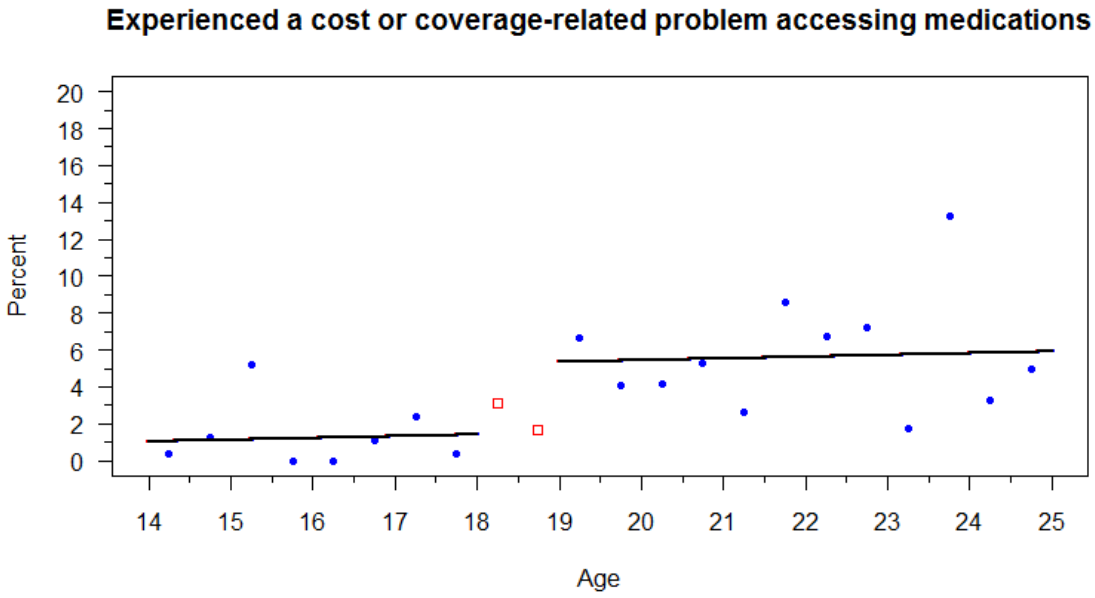


Figure 3.1, continued

G.



H.



DISCUSSION

In this nationally representative study, young adults with asthma were less likely than older adolescents with asthma to have a usual source of care and less likely to use primary or preventive care. These findings suggest that young adults with asthma have worse health care access and receive suboptimal care, as national guidelines recommend that young adults with asthma be seen at least every 6 months to monitor control.[11] Young adults with asthma were also less likely to fill SABA prescriptions and more likely to experience cost and coverage-related access problems. Most of these differences were reduced substantially after adjusting for differences in insurance coverage.

In addition, young adults with asthma were more likely to visit EDs, consistent with previous research demonstrating that young adults in general rely on EDs for care more than adolescents.[8] Our findings suggest a possible substitution of ED care for primary care by young adults with asthma. Such a substitution would be economically inefficient because ED care is more expensive than office-based care for similar conditions,[17] as well as clinically important if the substitution resulted from poor disease control or led to poorly coordinated care.

Differences in insurance coverage between age groups did not explain the higher ED use by young adults with asthma. This finding suggests that other factors were involved or that insurance coverage has offsetting effects on non-emergent and emergent ED use in this population. Previous research examining the role of insurance coverage in ED use has produced mixed results.[18] In one quasi-experimental study, coverage losses at age 19 were associated with decreased overall ED use among young adults.[19] In

another study, however, individuals who gained Medicaid coverage through a lottery in Oregon did not significantly increase their ED use.[20] The effects of insurance coverage on emergent and non-emergent ED use by young adults are unclear.

In longitudinal analyses of participants with asthma transitioning from adolescence to young adulthood, becoming uninsured strongly predicted losing a usual source of care. This finding is consistent with a prior cross-sectional study demonstrating that uninsured young adults are less likely to have a usual source of care than their insured counterparts.[21] Becoming uninsured was also associated with a large decrease in primary care visits, though this change was not statistically significant.

Discontinuing schooling was associated with decreased use of primary and preventive care, while transitioning to independent living was associated with greater fills of SABA prescriptions. There are several potential explanations for these findings. Non-students may face greater time costs when accessing primary and preventive care than full-time students, who are more likely to have convenient access to student health services.[22] Previous research suggests that familial support improves asthma control in adolescents.[23] As such, it is possible that individuals with asthma develop worse disease control after moving away from their families, leading to greater SABA inhaler use. Due to a lack of data on such mediators, however, we could not empirically test these potential explanations.

Our study has several other limitations. First, we could not examine ED visits for asthma exacerbations or otherwise measure asthma control. Second, we excluded participants aged 18 from cross-sectional analyses because many transitions in insurance, schooling, and living situations occur at this age. However, these transitions could have

occurred earlier or later for any given participant. Third, inconsistencies between proxy and self-reports may have contributed to reported differences in access and utilization between age groups. However, our cross-sectional results did not substantively change when we excluded older participants who consistently self-reported information because they no longer lived with their families. Thus, any reporting bias was likely small, consistent with previous studies demonstrating high concordance between parent and adolescent reports of asthma-related office visits, ED visits, and medication use.[24,25]

Finally, we did not adjust our comparisons for socioeconomic status because of inconsistencies in the meaning of household income information across age groups. Specifically, for participants living with their parents and unmarried college students living away from home, household income information collected by the survey usually refers to parental income. For young adults living independently, however, this information represents the young adult's income.

Our findings have important clinical implications. Many adolescents with asthma may experience disruptions in care as they become young adults, with potentially deleterious clinical consequences. Disruptions may be particularly pronounced for adolescents with asthma who lose insurance coverage, discontinue schooling, and move away from home. For these patients, pediatric clinicians could implement comprehensive plans to facilitate smooth transitions to adult care.[26]

Our findings also have important policy implications. The ACA allows dependent children to remain on private family policies until age 26 and will expand Medicaid eligibility to childless adults with incomes up to 133% of the federal poverty level starting in 2014.[3] Thus, as the ACA is implemented, the number of uninsured

young adults will likely fall dramatically. Our study suggests that these coverage expansions may substantially improve access to care for young adults with asthma. Indeed, implementation of the ACA dependent coverage provision in 2010 has already been associated with modest reductions in uninsurance among young adults,[4,27] and similar state laws in 2005-2006 were associated with improved access among young adults.[28] Our study also suggests that expanding coverage may improve care for young adults with asthma. Adjusting for differences in insurance coverage in this population explained 32% of their lower use of primary care and 47-61% of their greater problems accessing medical care or medications due to cost or coverage issues.

Differences in insurance coverage, however, did not fully explain differences in access or use of recommended care between adolescents and young adults with asthma. We identified other social factors that may contribute to differences in primary and preventive care use. In addition, differences in coverage did not substantially explain the higher ED use among young adults with asthma. These findings suggest that coverage expansions supported by the ACA might not fully address suboptimal utilization patterns among young adults with asthma.

CONCLUSION

Compared to older adolescents with asthma, young adults with asthma have worse health care access and may use care less optimally. Although losing insurance coverage may contribute to these differences, other social factors may also play important roles.

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APPENDIX FOR CHAPTER 1

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Appendix 1.1. Definitions of management decisions

1) *Urine test:* urine culture[a] or a urine test with one of the following descriptions:

Microscopic examination of urine
Urinalysis, unspecified
Chemical examination of urine
Complete urinalysis
Macroscopic urinalysis
Other specified urinalysis

2) *Blood test:* blood culture or a blood test with one of the following descriptions:

Complete blood count, unspecified
Complete blood count with differential
Complete blood count without differential

3) *CSF test:* CSF culture, presence of a charge for lumbar puncture, or a CSF test with one of the following descriptions:

Glucose
Total protein
Hematology exam, other body fluid
Microbial identification, nucleic acid probe
Microbial identification, nucleic acid probe with amplification

4) *Parenteral antibiotic*: any antibiotic administered intravenously or intramuscularly

5) *Hospitalization:* admission to the observation unit or inpatient setting

[a]We defined a "culture" as a lab test with one of the following descriptions:

Bacterial cultures, unspecified
Aerobic culture
Culture with antimicrobial removal device
Anaerobic culture
Aerobic and anaerobic culture
Other specified bacterial culture

Appendix 1.2. Regression specification and simulation procedure for transforming difference-in-differences estimates

Regression specification

We estimated the following generalized linear model (GLM):

$$g[E(Y_{ij})]=\beta_0+\beta_1 \text{Older}_i +\beta_2 \text{Older}_i*\text{CPG}_j + \beta_3\text{Hospitalfixedeffects}_j + \beta_4 \text{Covariates}_i$$

In this model, $E(Y_{ij})$ is the expected outcome (adverse events or standardized spending) for infant i in hospital j, Older_i is an indicator of age group (older versus younger febrile infant), CPG_j is an indicator of CPG group (CPG versus control), and g is the link function. For models of adverse events, we used a logit link (logistic regression); for models of standardized spending, we used a log link and a gamma family variance function based on the modified Park test.[18] We included hospital fixed effects (i.e. indicators for each hospital, omitting one hospital) to control for hospital-specific factors common to younger and older febrile infants, such as geographic location and the case mix of infants served by the hospitals.

Simulation procedure for transforming difference-in-differences estimates

GLM with logit link: adverse events

After fitting a generalized linear model predicting the log odds of an adverse event, we set the vectors of coefficients and standard errors from the model to the parameters of a multivariate normal distribution. In each of 1,000 simulation loops, we sampled coefficient values from this distribution and used these values to calculate the fitted values for each observation when 1) the indicator for age group was set to 1 (older infant) and the interaction term was set to 1, holding all other covariates constant; and 2) when the indicator for age group was set to 1 and the interaction term was set to 0,

holding all other covariates constant. We transformed these fitted values to the probability scale using the inverse logit function, then calculated their difference. The average of these differences over all observations in the sample was the estimate of the difference-in-differences effect for that simulation loop. The mean and standard deviation of the 1,000 simulation estimates were the point estimate and standard error of the difference-in-differences estimate, respectively. We calculated the p value based on a two-sided t-test with 999 degrees of freedom.

GLM with log link: standardized spending

The simulation procedure was identical, except that we transformed fitted values to the dollar scale using exponentiation.

Appendix 1.3. Assessing for diverging trends among younger febrile infants

We tested whether differences in adverse events or standardized spending between comparison groups changed with increasing age among younger febrile infants. After restricting the sample to younger febrile infants, we fitted generalized linear models predicting adverse events or standardized spending as a function of age in days, the indicator of CPG group status (CPG vs. control), and their interaction. Analyses were adjusted for covariates and used robust variance estimators to account for clustering at the hospital level. Among younger febrile infants, age trends diverged slightly, though not significantly, for adverse events ($p=0.87$) and standardized spending ($p=0.11$).

One potential explanation for the slight divergence in trends among younger febrile infants is the existence of differences in case mix between comparison groups evolving with age. However, results were not substantively different from the main results when we adjusted for pre-existing trends, suggesting that any evolving differences in case mix were likely small.

The other explanation is that physicians in the control group may have deferred CSF testing for well-appearing febrile infants with reassuring urine and blood test results if these infants were close to the 29-day threshold. These anticipatory changes in practice were suggested by the small decrease in CSF testing among younger febrile infants aged 21-28 days in the control group and the lack of such a decrease in the CPG group. If present, the anticipatory changes could unmask existing case mix differences between comparison groups among younger febrile infants. However, results were not substantively different when we excluded febrile infants aged 21-28 days from the

sample, suggesting that any bias secondary to anticipatory changes in practice was likely minimal.

Appendix 1.4. Details of sensitivity analysis excluding hospitals with competitors in the same metropolitan statistical area

Using information from the website of the Children's Hospital Association, we identified 14 PHIS hospitals in our sample that were located in metropolitan statistical areas with at least one other general children's hospital. We did not count rehabilitation hospitals or specialty hospitals like Shriner's Hospitals, as these hospitals do not take care of febrile infants. None of the competitor hospitals were one of the other 31 PHIS hospitals included in our sample. In a sensitivity analysis, we excluded the 14 PHIS hospitals with nearby competitors, hypothesizing that febrile infants initially presenting to these hospitals were more likely to be readmitted to a competing hospital (thereby causing a data capture issue) than febrile infants initially presenting to PHIS hospitals without nearby competitors.

We also assessed whether having a nearby competitor is a reasonable proxy for low market share. For this analysis, we examined the 2009 Kids' Inpatient Database (KID), a national sample of U.S. pediatric hospitalizations that is part of the family of databases from the Healthcare Cost and Utilization Project (U.S. Agency for Healthcare Research and Quality). We were able to identify 17 of the 31 PHIS hospitals in our sample based on American Hospital Association identifiers; we excluded three of these hospitals with missing data for age in months in the KID. We estimated the market share of each of the remaining hospitals by dividing the weighted number of non-birth inpatient admissions for infants less than two months of age at the hospital by the weighted total number of such admissions in the hospital's metropolitan statistical area. In this analysis, there were seven hospitals with nearby competitors; market share ranged from 18.1% to 66.3% with a median of 45.1%. There were seven hospitals without nearby competitors;

market share ranged from 54.7% to 90.1% with a median of 77.5%. These findings suggested that PHIS hospitals with nearby competitors do have lower market share than hospitals without nearby competitors, providing support for our approach.

Appendix Table 1.1. ICD-9 diagnosis codes used to construct sample

Code	Title	Percent of infants aged 7-28 days with diagnosis code in discharge record who underwent a complete sepsis evaluation	Number of infants aged 7-28 days with diagnosis code in discharge record
027.0	Listeriosis	100	13
711.01	Pyogenic arthritis, shoulder region	100	10
320.7	Meningitis in other bacterial diseases classified elsewhere	100	9
382.01	Acute suppurative otitis media with spontaneous rupture of eardrum	100	6
V09.81	Infection with microorganisms resistant to other specified drugs with resistance to multiple drugs	100	6
038.8	Other specified septicemias	100	5
320.1	Pneumococcal meningitis	100	4
730.22	Unspecified osteomyelitis, upper arm	100	4
040.41	Infant botulism	100	3
051.2	Contagious pustular dermatitis	100	3
079.1	ECHO virus infection in conditions classified elsewhere and	100	3
098.0	Gonococcal infection (acute) of lower genitourinary tract	100	3
320.81	Meningitis due to anaerobic bacteria	100	3
484.8	Pneumonia in other infectious diseases classified elsewhere	100	3
997.31	Ventilator associated pneumonia	100	3
003.8	Other specified salmonella infections	100	2
008.63	Enteritis due to Norwalk virus	100	2
036.0	Meningococcal meningitis	100	2
041.82	Bacterial infection due to Bacteroides fragilis	100	2
047.1	Meningitis due to ECHO virus	100	2
049.1	Non-arthropod borne meningitis due to adenovirus	100	2
049.8	Other specified non-arthropod-borne viral diseases of central nervous system	100	2
070.59	Other specified viral hepatitis without mention of hepatic coma	100	2
112.4	Candidiasis of lung	100	2
360.19	Other endophthalmitis	100	2
384.20	Perforation of tympanic membrane, unspecified	100	2
478.24	Retropharyngeal abscess	100	2
482.31	Pneumonia due to Streptococcus, group A	100	2
482.39	Pneumonia due to other Streptococcus	100	2
485	Bronchopneumonia, organism unspecified	100	2
488.0	Influenza due to identified avian influenza virus	100	2

Appendix Table 1.1, continued

680.0	Carbuncle and furuncle of face	100	2
729.4	Fasciitis, unspecified	100	2
730.02	Acute osteomyelitis, upper arm	100	2
730.21	Unspecified osteomyelitis, shoulder region	100	2
730.24	Unspecified osteomyelitis, hand	100	2
999.33	Local infection due to central venous catheter	100	2
003.21	Salmonella meningitis	100	1
004.3	Shigella sonnei	100	1
008.00	Intestinal infection due to unspecified E. coli	100	1
008.3	Intestinal infection due to Proteus (mirabilis) (morganii)	100	1
008.44	Intestinal infection due to Yersinia enterocolitica	100	1
035	Erysipelas	100	1
036.89	Other specified meningococcal infections	100	1
036.9	Meningococcal infection, unspecified	100	1
038.3	Septicemia due to anaerobes	100	1
038.44	Septicemia due to Serratia	100	1
040.82	Toxic shock syndrome	100	1
041.86	Helicobacter pylori [H. pylori] infection	100	1
053.0	Herpes zoster with meningitis	100	1
053.20	Herpes zoster dermatitis of eyelid	100	1
053.21	Herpes zoster keratoconjunctivitis	100	1
054.0	Eczema herpeticum	100	1
054.13	Herpetic infection of penis	100	1
054.40	Herpes simplex with unspecified ophthalmic complication	100	1
054.41	Herpes simplex dermatitis of eyelid	100	1
054.6	Herpetic whitlow	100	1
058.89	Other human herpesvirus infection	100	1
078.88	Other specified diseases due to Chlamydiae	100	1
079.4	Human papillomavirus infection in conditions classified elsewhere and of unspecified site	100	1
093.89	Other specified cardiovascular syphilis	100	1
094.2	Syphilitic meningitis	100	1
099.9	Venereal disease, unspecified	100	1
322.2	Chronic meningitis	100	1
323.01	Encephalitis and encephalomyelitis in viral diseases classified elsewhere	100	1
324.1	Intraspinal abscess	100	1
360.01	Acute endophthalmitis	100	1
380.13	Other acute infections of external ear	100	1
381.02	Acute mucoid otitis media	100	1

Appendix Table 1.1, continued

382.3	Unspecified chronic suppurative otitis media	100	1
383.1	Chronic mastoiditis	100	1
473.2	Chronic ethmoidal sinusitis	100	1
473.8	Other chronic sinusitis	100	1
478.22	Parapharyngeal abscess	100	1
482.1	Pneumonia due to Pseudomonas	100	1
484.7	Pneumonia in other systemic mycoses	100	1
488.09	Influenza due to identified avian influenza virus with other manifestations	100	1
488.19	Influenza due to identified novel H1N1 influenza virus with other manifestations	100	1
488.81	Influenza due to identified novel influenza A virus with pneumonia	100	1
488.89	Influenza due to identified novel influenza A virus with other mani	100	1
492.8	Other emphysema	100	1
511.1	Pleurisy with effusion, with mention of a bacterial cause ot	100	1
519.01	Infection of tracheostomy	100	1
528.3	Cellulitis and abscess of oral soft tissues	100	1
730.03	Acute osteomyelitis, forearm	100	1
730.13	Chronic osteomyelitis, forearm	100	1
730.15	Chronic osteomyelitis, pelvic region and thigh	100	1
730.36	Periostitis, without mention of osteomyelitis, lower leg	100	1
996.68	Infection and inflammatory reaction due to peritoneal dialysis catheter	100	1
V09.4	Infection with microorganisms resistant to aminoglycosides	100	1
V09.50	Infection with microorganisms resistant to quinolones and fluoroquinolones without mention of resistance to multiple quinolones and fluoroquinolones	100	1
054.79	Herpes simplex with other specified complications	92.9	14
590.10	Acute pyelonephritis without lesion of renal medullary necrosis	92.6	136
047.9	Unspecified viral meningitis	90.1	717
048	Other enterovirus diseases of central nervous system	90	20
488.1	Influenza due to identified novel H1N1 influenza virus	89.5	19
047.8	Other specified viral meningitis	89	848
038.42	Septicemia due to Escherichia coli [E. coli]	87.5	8
054.5	Herpetic septicemia	87.5	8
320.3	Staphylococcal meningitis	87.5	8
054.43	Herpes simplex disciform keratitis	86.7	15
320.89	Meningitis due to other specified bacteria	86.7	15
780.61	Fever presenting with conditions classified elsewhere	86.4	147
320.2	Streptococcal meningitis	85.9	99

Appendix Table 1.1, continued

054.2	Herpetic gingivostomatitis	85.7	7
079.2	Coxsackie virus infection in conditions classified elsewhere and of unspecified site	85.7	7
711.06	Pyogenic arthritis, lower leg	85.7	7
057.8	Other specified viral exanthemata	85	40
041.49	Other and unspecified Escherichia coli [E. coli]	84.7	680
041.4	Escherichia coli [E. coli] infection in conditions classified elsewhere and of unspecified site	84.5	1393
V29.0	Observation and evaluation of newborns and infants for suspected infectious condition	84.4	1898
320.9	Meningitis due to unspecified bacterium	84.4	64
590.80	Pyelonephritis, unspecified	83.9	461
038.9	Unspecified septicemia	83.9	199
771.81	Septicemia [sepsis] of newborn	83.6	2638
008.67	Enteritis due to enterovirus not elsewhere classified	83.3	12
038.0	Streptococcal septicemia	83.3	12
003.9	Salmonella infection, unspecified	83.3	6
049.9	Unspecified non-arthropod-borne viral diseases of central nervous system	83.3	6
381.01	Acute serous otitis media	83.3	6
488.12	Influenza due to identified novel H1N1 influenza virus with other respiratory manifestations	83.3	6
771.82	Urinary tract infection of newborn	82.6	2521
320.82	Meningitis due to gram-negative bacteria, not elsewhere classified	82.4	91
054.3	Herpetic meningoencephalitis	82.1	56
323.9	Unspecified causes of encephalitis, myelitis, and encephalomyelitis	81.8	11
595.9	Cystitis, unspecified	81.8	11
778.4	Other disturbances of temperature regulation of newborn	80.7	13032
041.02	Bacterial infection due to Streptococcus, group B	80.6	310
995.91	Sepsis	80.4	107
324.0	Intracranial abscess	80	10
728.0	Infective myositis	80	10
038.49	Other septicemia due to gram-negative organisms	80	5
482.32	Pneumonia due to Streptococcus, group B	80	5
730.28	Unspecified osteomyelitis, other specified sites	80	5
995.90	Systemic inflammatory response syndrome, unspecified	80	5
322.9	Meningitis, unspecified	79.5	302
771.83	Bacteremia of newborn	79	538
480.8	Pneumonia due to other virus not elsewhere classified	78.6	14
487.8	Influenza with other manifestations	78.6	14
599.0	Urinary tract infection, site not specified	78.5	432

Appendix Table 1.1, continued

790.8	Unspecified viremia	76.9	13
785.50	Shock, unspecified	76.7	30
041.04	Bacterial infection due to Streptococcus, group D [Enterococcus]	76.5	311
382.4	Unspecified suppurative otitis media	75	8
033.1	Whooping cough due to Bordetella parapertussis [B. parapertussis]	75	4
038.11	Methicillin susceptible Staphylococcus aureus septicemia	75	4
058.10	Roseola infantum, unspecified	75	4
070.9	Unspecified viral hepatitis without mention of hepatic coma	75	4
370.9	Unspecified keratitis	75	4
730.26	Unspecified osteomyelitis, lower leg	75	4
762.7	Chorioamnionitis affecting fetus or newborn	75	4
770.0	Congenital pneumonia	74.6	189
464.10	Acute tracheitis without mention of obstruction	74.4	43
041.84	Bacterial infection due to other anaerobes	73.7	19
325	Phlebitis and thrombophlebitis of intracranial venous sinuses	73.7	19
054.72	Herpes simplex meningitis	73.3	30
079.89	Other specified viral infection	73	806
041.89	Bacterial infection due to other specified bacteria	73	122
995.92	Severe sepsis	72.9	85
790.7	Bacteremia	72.7	139
711.05	Pyogenic arthritis, pelvic region and thigh	72.7	11
041.85	Bacterial infection due to other gram-negative organisms	72.4	344
078.89	Other specified diseases due to viruses	72.1	43
041.3	Klebsiella pneumoniae infection in conditions classified elsewhere and of unspecified site	72	214
480.2	Pneumonia due to parainfluenza virus	71.4	14
487.0	Influenza with pneumonia	71.4	14
482.42	Methicillin resistant pneumonia due to Staphylococcus aureus	71.4	7
V09.1	Infection with microorganisms resistant to cephalosporins and other B-lactam antibiotics	71.4	7
041.6	Proteus (mirabilis) (morganii) infection in conditions classified elsewhere and of unspecified site	70	30
785.59	Other shock without mention of trauma	70	30
041.7	Pseudomonas infection in conditions classified elsewhere and of unspecified site	70	20
785.52	Septic shock	69.2	78
481	Pneumococcal pneumonia [Streptococcus pneumoniae pneumonia]	69	29
041.01	Bacterial infection due to Streptococcus, group A	67.9	56
511.9	Unspecified pleural effusion	67.6	34

Appendix Table 1.1, continued

041.09	Bacterial infection due to other Streptococcus	66.7	102
054.9	Herpes simplex without mention of complication	66.7	102
527.2	Sialoadenitis	66.7	27
008.43	Intestinal infection due to Campylobacter	66.7	12
683	Acute lymphadenitis	66.7	12
573.3	Hepatitis, unspecified	66.7	9
V09.91	Infection with drug-resistant microorganisms, unspecified, with multiple drug resistance	66.7	9
996.62	Infection and inflammatory reaction due to other vascular device, implant, and graft	66.7	6
038.41	Septicemia due to Hemophilus influenzae [H. influenzae]	66.7	3
041.05	Bacterial infection due to Streptococcus, group G	66.7	3
058.29	Other human herpesvirus encephalitis	66.7	3
372.20	Blepharoconjunctivitis, unspecified	66.7	3
383.9	Unspecified mastoiditis	66.7	3
480.0	Pneumonia due to adenovirus	66.7	3
482.82	Pneumonia due to Escherichia coli [E. coli]	66.7	3
528.09	Other stomatitis and mucositis (ulcerative)	66.7	3
536.41	Infection of gastrostomy	66.7	3
567.22	Peritoneal abscess	66.7	3
573.1	Hepatitis in viral diseases classified elsewhere	66.7	3
577.0	Acute pancreatitis	66.7	3
590.2	Renal and perinephric abscess	66.7	3
695.19	Other erythema multiforme	66.7	3
711.02	Pyogenic arthritis, upper arm	66.7	3
728.86	Necrotizing fasciitis	66.7	3
730.20	Unspecified osteomyelitis, site unspecified	66.7	3
916.3	Blister of hip, thigh, leg, and ankle, infected	66.7	3
V09.3	Infection with microorganisms resistant to tetracyclines	66.7	3
003.0	Salmonella gastroenteritis	65.8	38
289.3	Lymphadenitis, unspecified, except mesenteric	65.6	32
041.5	Hemophilus influenzae [H. influenzae] infection in conditions classified elsewhere and of unspecified site	65.5	110
079.0	Adenovirus infection in conditions classified elsewhere and of unspecified site	65.4	26
079.3	Rhinovirus infection in conditions classified elsewhere and of unspecified site	65	712
695.1	Erythema multiforme	65	20
487.1	Influenza with other respiratory manifestations	64.4	637
041.2	Pneumococcus infection in conditions classified elsewhere and of unspecified site	64.3	28
074.3	Hand, foot, and mouth disease	63.6	11

Appendix Table 1.1, continued

373.13	Abscess of eyelid	63.5	115
008.61	Enteritis due to Rotavirus	63.3	79
482.0	Pneumonia due to Klebsiella pneumoniae	62.5	8
486	Pneumonia, organism unspecified	61.7	645
780.6	Fever and other physiologic disturbances of temperature regulation	60	1543
098.40	Gonococcal conjunctivitis (neonatorum)	60	20
090.1	Early congenital syphilis, latent	60	5
488.82	Influenza due to identified novel influenza A virus with other respiratory manifestations	59.1	22
057.9	Viral exanthem, unspecified	58.9	236
771.2	Other congenital infections specific to the perinatal period	58.7	436
730.25	Unspecified osteomyelitis, pelvic region and thigh	57.1	7
V09.2	Infection with microorganisms resistant to macrolides	57.1	7
079.88	Other specified chlamydial infection	55.6	9
604.90	Orchitis and epididymitis, unspecified	55.6	9
616.10	Vaginitis and vulvovaginitis, unspecified	55.6	9
482.2	Pneumonia due to Hemophilus influenzae [H. influenzae]	54.8	31
682.0	Cellulitis and abscess of face	54.7	148
041.00	Bacterial infection due to unspecified Streptococcus	54.2	24
V09.0	Infection with microorganisms resistant to penicillins	53.8	238
376.01	Orbital cellulitis	53.7	41
041.12	Methicillin resistant Staphylococcus aureus in conditions classified elsewhere and of unspecified site	52.9	427
760.2	Maternal infections affecting fetus or newborn	52.6	57
484.3	Pneumonia in whooping cough	52.6	19
771.89	Other infections specific to the perinatal period	51.9	5500
079.99	Unspecified viral infection	51.9	5267
482.9	Bacterial pneumonia, unspecified	51.6	124
041.19	Bacterial infection due to other Staphylococcus	51.2	203
041.11	Methicillin susceptible Staphylococcus aureus in conditions classified elsewhere and of unspecified site	51.1	820
695.81	Ritter's disease	50.6	81
041.9	Bacterial infection, unspecified, in conditions classified elsewhere and of unspecified site	50	62
682.7	Cellulitis and abscess of foot, except toes	50	22
999.31	Infection due to central venous catheter	50	12
V09.80	Infection with microorganisms resistant to other specified drugs without mention of resistance to multiple drugs	50	12
076.1	Trachoma, active stage	50	6
077.8	Other viral conjunctivitis	50	4
527.3	Abscess of salivary gland	50	4

Appendix Table 1.1, continued

597.89	Other urethritis	50	4
038.19	Other staphylococcal septicemia	50	2
076.9	Trachoma, unspecified	50	2
078.5	Cytomegaloviral disease	50	2
090.0	Early congenital syphilis, symptomatic	50	2
372.04	Pseudomembranous conjunctivitis	50	2
379.00	Scleritis, unspecified	50	2
380.22	Other acute otitis externa	50	2
461.0	Acute maxillary sinusitis	50	2
46.	Acute tonsillitis	50	2
482.40	Pneumonia due to Staphylococcus, unspecified	50	2
488.02	Influenza due to identified avian influenza virus with other respiratory manifestations	50	2
519.2	Mediastinitis	50	2
595.0	Acute cystitis	50	2
603.1	Infected hydrocele	50	2
680.3	Carbuncle and furuncle of upper arm and forearm	50	2
680.8	Carbuncle and furuncle of other specified sites	50	2
711.04	Pyogenic arthritis, hand	50	2
730.05	Acute osteomyelitis, pelvic region and thigh	50	2
730.27	Unspecified osteomyelitis, ankle and foot	50	2
771.3	Tetanus neonatorum	50	2
996.64	Infection and inflammatory reaction due to indwelling urinary catheter	50	2
780.60	Fever, unspecified	47	4458

APPENDIX FOR CHAPTER 2

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Appendix 2.1. Simulation procedure for calculating difference-in-differences estimates

After fitting a generalized linear model predicting expenditures, we set the vectors of coefficients and standard errors from the model to the parameters of a multivariate normal distribution. In each of 1,000 simulation loops, we sampled coefficient values from this distribution. Using these coefficients, we calculated the fitted values for each observation when 1) the indicators for post period and treatment group were set to 1 and the interaction term was set to 1, holding all other covariates constant; and 2) when the indicator for post period was set to 1, the indicator for treatment group was set to 0, and the interaction term was set to 0, holding all other covariates constant. We transformed these fitted values to the dollar scale via exponentiation, then calculated their difference. We then repeated this procedure when: 1) the indicator for post period was set to 1, the indicator for treatment group were set to 0, and the interaction term was set to 0, holding all other covariates constant; and 2) when the indicators for post period and treatment group were set to 0 and the interaction term was set to 0, holding all other covariates constant. The difference between these two differences was the difference-in-differences estimate for that observation. The average of these estimates over all observations in the sample was the estimate of the difference-in-differences effect for the simulation loop. The mean and standard deviation of the 1,000 simulation estimates were the point estimate and standard error of the difference-in-differences estimate, respectively. We calculated the p value based on a two-sided t-test with 999 degrees of freedom.

Appendix 2.2. Adjustment for pre-existing trends

The regression specification for binary outcomes in the main analysis was:

$$E(Y_i)= \beta_0 + \beta_1*Treatment_i + \beta_2*Post_i + \beta_3*Treatment_i*Post_i + \gamma*X_i$$

In this regression, Y_i is the outcome for the *i*th observation, $Post_i$ is a binary variable that equals 1 if the *i*th observation came from 2011-2012, $Treatment_i$ is a binary variable that equals 1 if the *i*th observation came from a young adult aged 19-25, and X_i is a vector of covariates.

In a sensitivity analyses, we adjusted for pre-existing diverging trends by allowing for a differential slope and level change in the post period:

$$E(Y_i)= \beta_0 + \beta_1*Treatment_i + \beta_2*Post_i + \beta_3*Treatment_i*Post_i + \beta_4*Datayear_i + \beta_5*Datayear_i*Treatment_i + \beta_6*(Datayear-2002)_i*Post_i + \beta_7*(Datayear-2002)_i*Treatment_i * Post_i + \gamma*X_i$$

We then used Stata's margins command to calculate a weighted average of the difference-in-differences effects in 2011 (differential level change plus the differential slope change) and 2012 (differential level change plus two times the differential slope change).

Results from trend-adjusted analyses are shown in Table 2.4. For having health insurance coverage, having private health insurance coverage, and total annual out-of-pocket expenditures, point estimates attenuated but remained statistically significant. For self-reported physical health, and self-reported mental health, and percent of annual health care expenditures paid out-of-pocket, point estimates attenuated and lost statistical significance. However, these estimates did not switch signs and suggested effects that were consistent with our conclusions.

The trend-adjusted and non-trend-adjusted analyses likely represent reasonable bounds of the effect of the provision. One reason to favor the trend-adjusted estimates

would be the existence of unobserved confounders differentially changing over time between comparison groups. As discussed in the text, we did not find any evidence of large differential changes in observable characteristics, suggesting that there were no large differential changes in unobservable characteristics (Table 2.5). Therefore, we presented the non-trend-adjusted analyses as the main results.

APPENDIX FOR CHAPTER 3

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Appendix 3.1. Specification and interpretation of linear regression models used for longitudinal comparisons

In our longitudinal analyses, we fitted the following linear regression model:

$$OUTCOME_{iy} = intercept + \beta_1*YEAR2_{iy} + \beta_2*LOSSOFINSURANCE_i + \beta_3*STOPSCHOOL_i + \beta_4*LOSSOFADULT_i + \beta_5*LOSSOFINSURANCE_i*YEAR2_{iy} + \beta_6*STOPSCHOOL_i*YEAR2_{iy} + \beta_7*LOSSOFADULT_i*YEAR2_{iy} + covariates$$

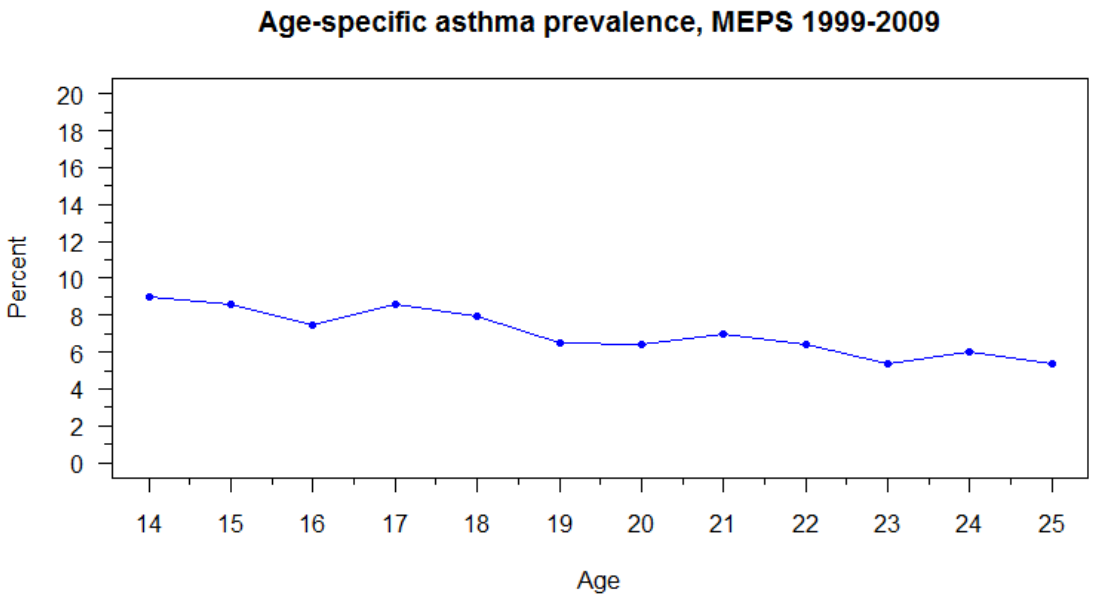
In this model, $OUTCOME_{iy}$ is the outcome for individual i in year y (1 or 2) and $YEAR2_{iy}$ is a dummy variable that indicates whether the data for individual i comes from year y (1 or 2). $LOSSOFINSURANCE_i$, $STOPSCHOOL_i$, and $LOSSOFADULT_i$ are the predictor variables describing changes in insurance coverage, schooling, and adult presence at home between year 1 and year 2 for individual i. Covariates include age dummies representing age in years at the beginning of MEPS participation, gender, race, region in year 1, residence in a Metropolitan Statistical Area in year 1, and data year (MEPS panel). The following describes the interpretation of the coefficients of interest:

- β_1: The change in outcome between year 1 and year 2, in the absence of changes in insurance coverage, schooling, or adult presence at home from year 1 to year 2.
- β_5: The additional/differential change in outcome in year 2 (relative to β_1) that is associated with transitioning from continuous insurance coverage in year 1 to continuous uninsurance in year 2, controlling for changes in schooling and adult presence at home.
- β_6: The additional/differential change in outcome in year 2 (relative to β_1) that is associated with transitioning from continuous full-time schooling in year 1 to no schooling in year 2, controlling for changes in insurance coverage and adult presence at home.

- β_7: The additional/differential change in outcome in year 2 (relative to β_1) that is associated with transitioning from continuous adult presence at home in year 1 to continuous independent living in year 2, controlling for changes in insurance coverage and schooling.

Appendix 3.2. Additional analyses addressing potential response bias

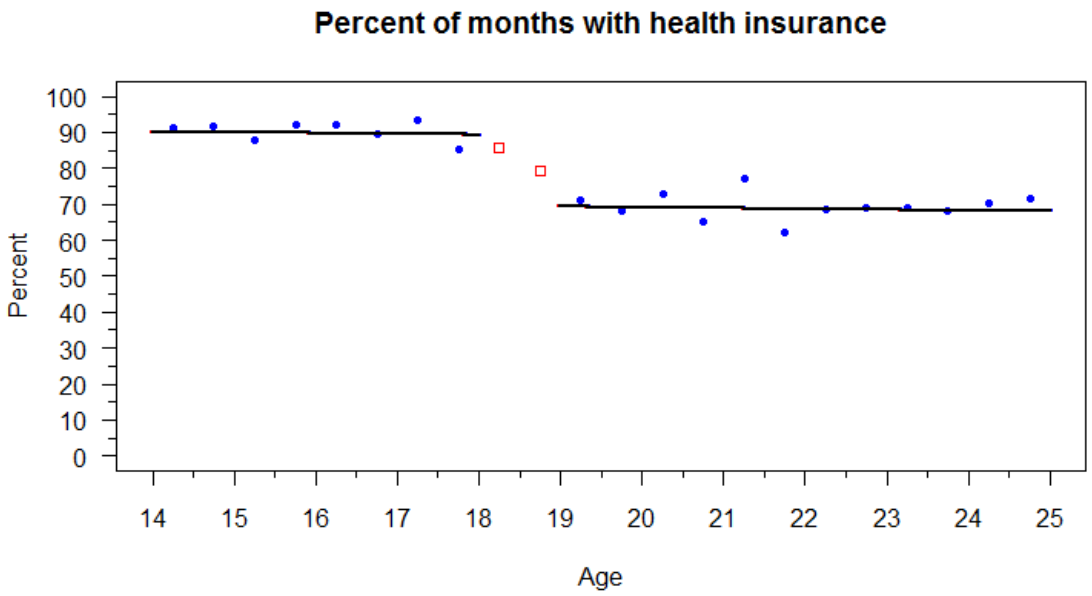
One potential threat to our study is sample selection bias introduced by age-related differences in responses to asthma-related questions, thereby leading to compositional differences between age groups in asthma severity and other unobserved factors. However, the results of our cross-sectional analyses were consistent with the results of our longitudinal analyses, in which there was no age-related compositional change in the sample by definition. Thus, age-related compositional changes in our sample are unlikely to explain our findings. In addition, we examined the age profile of asthma prevalence, using the definition of asthma from the cross-sectional analyses. If there were differential entry into the sample because young adults with asthma were more or less likely to report asthma-related health care utilization or a current diagnosis of asthma, one would expect an abrupt change in asthma prevalence around age 18. However, as shown in the graph below, there is no evidence of such a change.



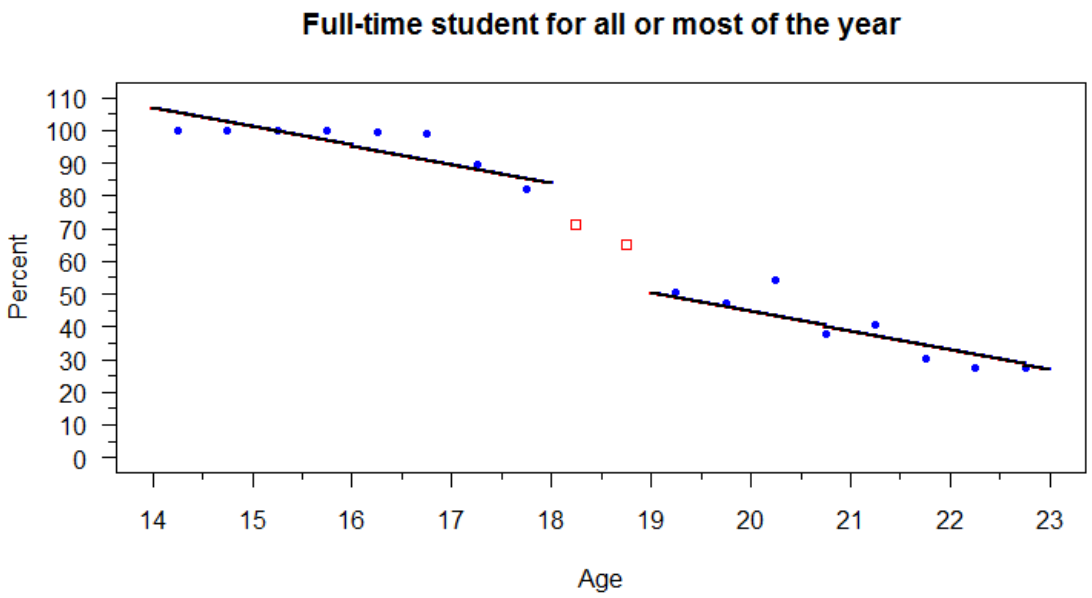
Appendix Figure 3.1. Changes in health insurance coverage, schooling, and adult presence at home among participants aged 14-25 with asthma, MEPS 1999-2009. Student status information was only collected from participants aged 17-23 in the MEPS. To construct the graph of changes in schooling, we assumed that all participants aged 14-16 were full-time students and excluded data from participants aged 24-25. Using data from MEPS rounds 1-3 or 3-5, we classified participants as full-time students for all or most of the year if they were full-time students at the end of at least 2 of the 3 rounds. We applied similar criteria to identify participants with continuous adult presence at home for all or most of the year. To classify the small number of participants with missing data for schooling or adult presence at home, we used the rounds for which data were available for these individuals. The square data points represent excluded data for participants aged 18. A) Percent of months with health insurance coverage; B) Percent of participants who were full-time students for all or most of the year; C) Percent of participants who had a continuous adult presence at home for all or most of the year.

Appendix Figure 3.1, continued

A.



B.



Appendix Figure 3.1, continued

C.